U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-289 497

Short Course Proceedings, Applications of Computer Programs in the Preliminary Design of Wastewater Treatment Facilities. Section II
User's Guide and Program Listing

Illinois Inst. of Tech., Chicago

Prepared for

Municipal Environmental Research Lab., Cincinnati, OH

Sep 78

United States
Environmental Protection
Agency

Municipal Environmental Research
Laboratory
Cincinnati OH 45268

EPA-600/2-78-185b
September 1978

Research and Development

PB 289497

EPA

Short Course Proceedings Applications of Computer Programs in the Preliminary Design of Wastewater Treatment Facilities

Section II
Users' Guide and Program Listing

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

RESEARCH REPORTING SERIES

Research reports of the Office of Research and Development, U.S. Environmental Protection Agency, have been grouped into nine series. These nine broad categories were established to facilitate further development and application of environmental technology. Elimination of traditional grouping was consciously planned to foster technology transfer and a maximum interface in related fields. The nine series are:

1. Environmental Health Effects Research
2. Environmental Protection Technology
3. Ecological Research
4. Environmental Monitoring
5. Socioeconomic Environmental Studies
6. Scientific and Technical Assessment Reports (STAR)
7. Interagency Energy-Environment Research and Development
8. "Special" Reports
9. Miscellaneous Reports

This report has been assigned to the ENVIRONMENTAL PROTECTION TECHNOLOGY series. This series describes research performed to develop and demonstrate instrumentation, equipment, and methodology to repair or prevent environmental degradation from point and non-point sources of pollution. This work provides the new or improved technology required for the control and treatment of pollution sources to meet environmental quality standards.

This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-78-185b

2.

3. RECIPIENT'S ACCESSION NO. PB289497

4. TITLE AND SUBTITLE
Short Course Proceedings; APPLICATIONS OF COMPUTER PROGRAMS IN THE PRELIMINARY DESIGN OF WASTEWATER TREATMENT FACILITIES; Section II: Users' Guide and Program Listing

5. REPORT DATE September 1978 (Issuing Date)

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
Richard G. Eilers, Robert Smith, Stephen P. Graef, James W. Male, Hisashi Ogawa, and Phong Nguyen

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Pritzker Department of Environmental Engineering
Illinois Institute of Technology
Chicago, Illinois 60616

10. PROGRAM ELEMENT NO. 1BC611

11. CONTRACT/GRANT NO. R-805134-01

12. SPONSORING AGENCY NAME AND ADDRESS
Municipal Environmental Research Laboratory--Cin.,OH
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

13. TYPE OF REPORT AND PERIOD COVERED Final

14. SPONSORING AGENCY CODE EPA/600/14

15. SUPPLEMENTARY NOTES
EPA Project Officer: Richard G. Eilers (513) 684-7618

16. ABSTRACT

This document contains a portion of the material used for the Short Course on the Applications of Computer Programs in Preliminary Design of Wastewater Treatment Facilities. The short course lectures appear in Section I of the report which is under separate cover. Section II, contained herein, contains the users' manual and program listing for the Executive Program for Preliminary Design of Wastewater Treatment Systems. The manual describes the use of the program and subroutines. Several examples show appropriate input and expected output for a variety of applications. In addition, the theoretical basis for the calculations are shown in the form of conventional mathematical and equivalent fortran equations. The program listing includes the main program and each of 27 subroutines, representing different treatment processes, energy consumption, and cost calculations.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Waste treatment *Models Sewage treatment Design *Cost estimates	*Performance *Cost effectiveness Mathematical models Sewage treatment Water pollution	Executive program Preliminary design Computer program Design engineering Sanitary engineering	13B

18. DISTRIBUTION STATEMENT
Release to Public

19. SECURITY CLASS *(This Report)* Unclassified

20. SECURITY CLASS *(This page)* Unclassified

21. NO. OF PAGES 288

22. PRICE PC A13
MF A01

☆ U. S. GOVERNMENT PRINTING OFFICE: 1978 — 657-060/1481

EPA-600/2-78-185b
September 1978

Short Course Proceedings

APPLICATIONS OF COMPUTER PROGRAMS IN THE PRELIMINARY DESIGN OF WASTEWATER TREATMENT FACILITIES

Section II: Users' Guide and Program Listing

by

Richard G. Eilers and Robert Smith
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

Stephen P. Graef
Metropolitan Sanitary District of Greater Chicago
Chicago, Illinois 60611

James W. Male
University of Massachusetts
Amherst, Massachusetts 01003

Hisashi Ogawa and Phong Nguyen
Illinois Institute of Technology
Chicago, Illinois 60616

Grant No. R-805134-01

Project Officer

Richard G. Eilers
Wastewater Research Division
Municipal Environmental Research Laboratory
Cincinnati, Ohio 45268

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

DISCLAIMER

This report has been reviewed by the Municipal Environmental Research Laboratory, U. S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U. S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimonies to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution, and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems to prevent, treat, and manage wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research--a most vital communications link between the research and the user community.

The information presented here is a users' guide for the Executive Program. This computer program provides the quantitative expressions for calculating the performance and cost of wastewater treatment systems as a function of the nature of the wastewater to be treated and the design criteria associated with the individual unit processes that comprise the system. As such, it can be a valuable tool to the design engineer for determining the most cost-effective system for achieving any specific wastewater treatment goal.

Francis T. Mayo
Director, Municipal Environmental
Research Laboratory

ABSTRACT

This document contains a portion of the material used for the Short Course on the Applications of Computer Programs in the Preliminary Design of Wastewater Treatment Facilities. The short course lectures appear in Section I of the report, under separate cover.

Section II, contained herein, contains the users' manual and program listing for the Executive Program for Preliminary Design of Wastewater Treatment Systems. The users' manual describes the use of the program and subroutines. Several examples show appropriate input and expected output for a variety of applications. In addition, the theoretical basis for the calculations are shown in the form of conventional mathematical and equivalent fortran equations.

The program listing includes the fortran listing for the main program (EXECMAIN) and each of the 27 subroutines, representing different treatment processes, energy consumption, and cost calculations. The program listings include extensive documentation and can be easily related to the theoretical equations in the users' manual.

This report was submitted in partial fulfillment of Grant Number R-805134-01 by the Pritzker Department of Environmental Engineering at the Illinois Institute of Technology under the sponsorship of the U. S. Environmental Protection Agency. This report covers a period from May 23, 1977 to June 22, 1978 and work was completed as of June 22, 1978.

CONTENTS

Foreword iii
Abstract iv
Figures viii
Tables ix
Acknowledgement x

1. Main Program, EXECMAIN 1
   Introduction 1
   Program Description 3
   Input Requirements 6
   Output 10
   Program Listing. 23
2. Preliminary Treatment, PREL. 29
   Users Guide. 29
   Program Listing. 32
3. Prelimary Sedimentation, PRSET 34
   Users Guide. 34
   Program Listing. 39
4. Activated Sludge - Final Settler, AERFS. 41
   Users Guide. 41
   Program Listing. 59
5. Stream Mixer, MIX. 64
   Users Guide. 64
   Program Listing. 66
6. Stream Splitter, SPLIT 67
   Users Guide. 67
   Program Listing. 68
7. Anaerobic Digestion, DIG 69
   Users Guide. 69
   Program Listing. 74
8. Vacuum Filtration, VACF. 77
   Users Guide. 77
   Program Listing. 83
9. Gravity Thickening, THICK. 85
   Users Guide. 85
   Program Listing. 90
10. Elutriation, ELUT. 92
   Users Guide. 92
   Program Listing. 98
11. Sand Drying Beds, SBEDS. 100
   Users Guide. 100
   Program Listing. 103
12. Trickling Filter - Final Settler, TRFS 105

CONTENTS (Cont.)

Users Guide 105
Program Listing 117
13. Chlorination - Dechlorination, CHLOR 121
Users Guide 121
Program Listing 126
14. Flotation Thickening, TFLOT 129
Users Guide 129
Program Listing 135
15. Multiple Hearth Incineration, MHINC 138
Users Guide 138
Program Listing 144
16. Raw Wastewater Pumping, RWP 147
Users Guide 147
Program Listing 150
17. Sludge Holding Tanks, SHT 152
Users Guide 152
Program Listing 155
18. Centrifugation, CENT 157
Users Guide 157
Program Listing 162
19. Aerobic Digestion, AEROB 165
Users Guide 165
Program Listing 178
20. Post Aeration, POSTA 182
Users Guide 182
Program Listing 194
21. Equalization, EQUAL 199
Users Guide 199
Program Listing 212
22. Second Stage Anaerobic Digestion, DIG2 218
Users Guide 218
Program Listing 222
23. Land Disposal of Liquid Sludge, LANDD. 224
Users Guide 224
Program Listing 229
24. Lime Addition to Sludge, LIME 232
Users Guide 232
Program Listing 235
25. Rotating Biological Contractor, RBC. 237
Users Guide 237
Program Listing 247
26. Energy Consumption and Cost, ENGY 250

CONTENTS (Cont.)

Program Listing 250
27. Total Plant Cost Calculation, COST 255
Users Guide 255
Program Listing 265
28. Output Subroutine, PRINT 268
Program Listing 268

References 274

FIGURES

Number Page

1 Example system flow diagram 4

2 Flowchart of EXECMAIN showing major branches and iterations.................................... 22

TABLES

Number Page

1 Unit processes contained in the executive program.. 2

2 Contents of the stream matrix (SMATX).............. 5

3 Sample output of process information............... 8

4 Arrangement 1 of Fortran format for input data cards.. 9

5 Arrangement 2 of Fortran format for input data cards.. 11

6 Sample output of stream characteristics............ 13

7 Sample output of process characteristics........... 16

8 Output showing total plant cost.................... 19

9 Output showing energy consumption and cost......... 20

ACKNOWLEDGEMENTS

Many people contributed to the preparation for the Short Course on Applications of Computer Programs in the Design of Wastewater Treatment Facilities. Without their efforts, arrangements would have been incomplete and material unprepared.

Contributing to the massive typing effort were Margaret Nolan, Mary Keeley, Pat Woods, Mary Pierce and Janet Peterson. In addition, Russ Ritchie helped with local arrangements and everyday details.

Resourses provided by both the U.S. Environmental Protection Agency and Illinois Institute of Technology are greatfully acknowledged.

SECTION 1

Main Program, EXECMAIN

INTRODUCTION

The Executive Program is a digital computer program which can be used to compute the quasi-steady-state performance and cost of wastewater treatment systems. Groups of conventional and advanced wastewater treatment processes arranged in any logical configuration can be simulated using this program. Table 1 gives a listing of the 24 unit process models that are presently included in the program along with the subroutine name and identification number for each process. Each unit process is handled as a separate subroutine, which makes it possible to add additional process models to the system as they are developed.

Initial development began on the Executive Program in 1967 and has continued until the present time. The program is written in FORTRAN IV. The complete FORTRAN source card listing of the computer program is included in this section. The system presently consists of the main program, entitled EXECMAIN, 24 process subroutines (each subroutine computes the performance and the costs associated with building and operating the unit process), and 3 additional subroutines entitled COST, PRINT, and ENGY. EXECMAIN reads the input data to the program, handles the iteration for system recycle streams, and calls the proper subroutines to perform the needed calculations. The COST subroutine sums and updates (by means of cost indicies) the costs of the individual processes and adds additional charges for yardwork, land, engineering, legal-fiscal-administrative services, and interest during construction. PRINT simply prints out all of the pertinent input and output data in a prescribed format. ENGY computes and prints out the energy requirements (electrical power, fuel oil, natural gas, etc.) associated with operating each unit process.

The Executive Program can be used as a valuable preliminary design tool by the consulting engineer or planner. The performance of existing and proposed wastewater treatment plants can be simulated along with providing cost estimates for building and operating these plants. It is also possible to mathematically optimize a particular treatment system by varying design parameters and noting the effect on performance and cost.

Subroutine Name	Identification Number
PREL, preliminary treatment	1
PRSET, primary sedimentation	2
AERFS, activated sludge-final settler	3
MIX, stream mixer	4
SPLIT, stream splitter	5
DIG, single stage anaerobic digestion	6
VACF, vacuum filtration	7
THICK, gravity thickening	8
ELUT, elutriation	9
SBEDS, sand drying beds	10
TRFS, trickling filter-final settler	11
CHLOR, chlorination-dechlorination	12
TFLOT, flotation thickening	13
MHINC, multiple hearth incineration	14
RWP, raw wastewater pumping	15
SHT, sludge holding tanks	16
CENT, centrifugation	17
AEROB, aerobic digestion	18
POSTA, post aeration	19
EQUAL, equalization	20
DIG2, second-stage anaerobic digestion	21
LANDD, land disposal of liquid sludge	22
LIME, lime additional to sludge	23
RBC, rotating biological contactor-final settler	24

Table 1 Unit processes contained in the executive program

Furthermore, alternate treatment systems can be compared with respect to performance and cost. Cost-effectiveness studies along these lines are becoming increasingly important because of the soaring construction costs that are now being experienced.

PROGRAM DESCRIPTION

The first step in using the Executive Program is to draw a system flow diagram showing the processes to be used and the connecting and recycle streams. The process symbols are shown in each of the Subroutine Users Guides. An example system flow diagram is shown in Figure 1. Each process and stream is assigned a number by the program user. Any stream can be numbered 2 through 30, and any process can be numbered 1 through 20. However, the principal influent stream to the system must always be assigned the number one (1). The number zero (0) must always be given to the processes that require no input decision data. Only the stream mixer (MIX) and the stream splitter (SPLIT) need no input data. Notice that the volume of the split stream must be supplied by a downstream process, such as gravity thickening, flotation thickening or sludge elutriation.

The program reads the influent stream characteristics and stores them with all the computed stream characteristics in the stream matrix (SMATX) which has 20 rows and 30 columns. One stream vector is stored in each column of SMATX corresponding to the user assigned stream number on the system diagram. A temporary stream matrix (TMATX) with 20 rows and 30 columns is used internally by the program to store newly computed stream vectors until they can be compared with the previously computed values during the program's recycle iterations. The iteration error (EPS) which will be tolerated when recycle streams are involved is designated by an easily changeable FORTRAN statement in EXECMAIN. The value for EPS currently used in the program is .10 mg/l. Each stream is referenced by the assigned stream number in the first row of SMATX, the volume flow in mgd in the second row, and the concentration of 17 contaminants in rows 3-19. Row 20 is unassigned at present, although, the number of contaminants contained in the stream vector may increase as new unit process subroutines are added to the program in the future. A list of the information contained in the stream vector is shown in Table 2 along with the FORTRAN variable names that are used.

A decision matrix (DMATX) is provided with 16 rows and 20 columns for storing input design parameters such as settler overflow rates, solids loading rates, detention times, chemical doses, and so on. One decision vector is stored in each column of DMATX corresponding to the user assigned process number on the system diagram. In other words, input parameters for process N are stored in the Nth column of DMATX. Column 20 of DMATX is reserved for cost parameters which apply to all

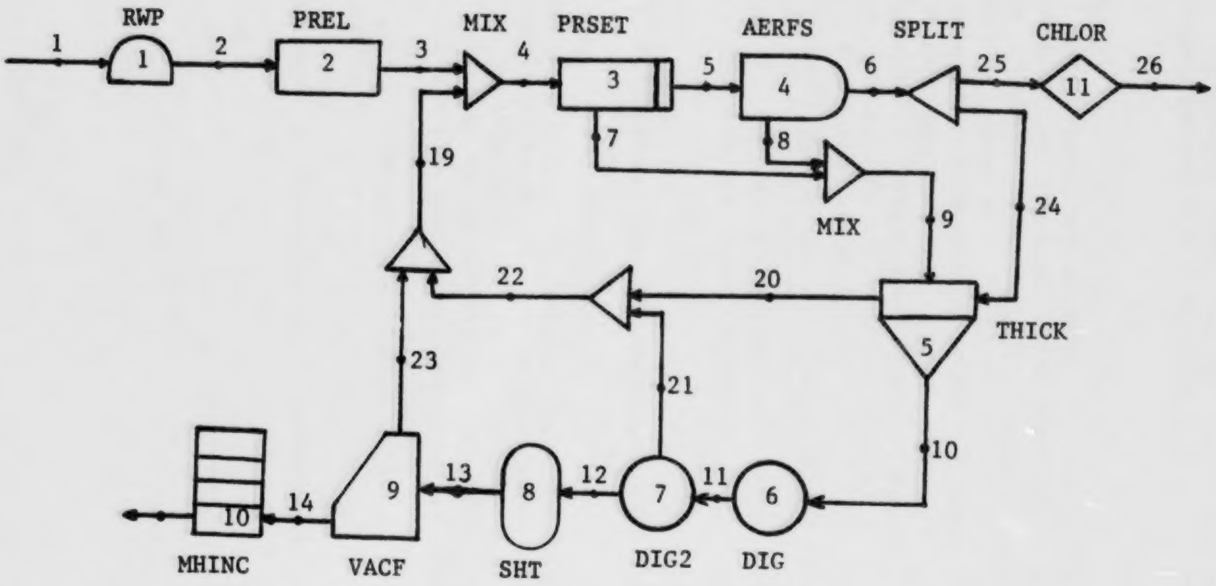

1
RWP
1
2
PREL
2
3
MIX
4
PRSET
3
5
AERFS
4
6
SPLIT
25
CHLOR
11
26
7
8
MIX
9
24
19
22
20
THICK
5
23
21
10
MHINC
10
14
VACF
9
13
SHT
8
12
DIG2
7
11
DIG
6

Figure 1 Example system flow diagram

Row Number	FORTRAN Variable Name		Parameter Definition	Nominal Value for Plant Influent
1	SMATX(1,I)	I	stream number	-
2	SMATX(2,I)	Q	volume flow, mgd	10.
3	SMATX(3,I)	SOC	solid organic carbon, mg/l	105.
4	SMATX(4,I)	SNBC	solid nonbiodegradable carbon, mg/l	30.
5	SMATX(5,I)	SON	solid organic nitrogen, mg/l	10.
6	SMATX(6,I)	SOP	solid organic phosphorus, mg/l	2.
7	SMATX(7,I)	SFM	solid fixed matter, mg/l	30.
8	SMATX(8,I)	SBOD	solid 5-day BOD, mg/l	140.
9	SMATX(9,I)	VSS	volatile suspended solids, mg/l	224.
10	SMATX(10,I)	TSS	total suspended solids, mg/l	254.
11	SMATX(11,I)	DOC	dissolved organic carbon, mg/l	43.
12	SMATX(12,I)	DNBC	dissolved nonbiodegradable carbon, mg/l	11.
13	SMATX(13,I)	DN	dissolved nitrogen, mg/l	19.
14	SMATX(14,I)	DP	dissolved phosphorus, mg/l	4.
15	SMATX(15,I)	DFM	dissolved fixed matter, mg/l	500.
16	SMATX(16,I)	ALK	alkalinity, mg/l	250.
17	SMATX(17,I)	DBOD	dissolved 5-day BOD, mg/l	60.
18	SMATX(18,I)	NH3	ammonia nitrogen as N, mg/l	15.
19	SMATX(19,I)	NO3	nitrate as N, mg/l	0.
20	not used			

Table 2 Contents of the stream matrix (SMATX)

processes, such as electrical power cost, construction cost index, hourly labor wage rates, and so on. Row 16 of DMATX (and additional preceding rows if required, such as in the AERFS process) is reserved for the excess capacity factor (ECF), which is a multiplier on the calculated design size of the process, to allow shutdown for cleaning and maintenance work.

For processes having a non-zero process number (N), the contents of the Nth column for DMATX are read into the program from 2 input data cards which follow the process card for the Nth process. For the stream mixer and the stream splitter, where no process number is assigned (the number "0" is given), the 2 cards containing decision parameters are omitted. A listing of the contents of DMATX for each unit process is given in the Subroutine Users Guides, along with definitions of the variables and nominal input values.

An output matrix (OMATX) is provided with 20 rows and 20 columns for storing computed output parameters from the various process subroutines. Output parameters for the Nth process are stored in the Nth column of OMATX. A listing of the contents of OMATX for each unit process is given in the subroutine Users Guides along with definitions of the computer output parameters.

The main program (EXECMAIN) has the function of calling the process subroutines for computing the performance and cost of the individual unit processes in the proper order. When a recycle loop occurs, this involves recomputing all of the processes within the recycle loop in an iterative manner until each element of all stream vectors ceases to vary by more than the prescribed tolerance (EPS).

INPUT REQUIREMENTS

A description of the system configuration (the process locations and interconnecting streams) is communicated to the computer by an input deck of process cards. One card is used for each process with the process number (N) punched in columns 3 and 4 (right-justified). The type of process is specified by an assigned identification number as given in the Subroutine Users Guides. This number is punched in columns 7 and 8 (right-justified) of the process card. If desired, the process subroutine name can be punched in columns 10 to 16 in order to clearly identify the process card and to include this information in the final program printout. The number of the principal input stream to the process (IS1) is punched in columns 20 and 21. If a second input stream exists, the number of the stream (IS2) is punched in columns 30 and 31. The principal output stream from the process (OS1) is punched in columns 40 and 41. If a second output stream exists, the number (OS2) is punched in columns 50 and 51. IS1, IS2, OS1 and OS2 are all punched as right-justified data. Notice that the principal input and output streams must correspond to the designation shown in the Subroutine Users Guides. The two DMATX input cards follow immediately after the process card where required. Also, the user should be careful to arrange the logical order of the process cards so that no streams are used before they are computed.

A listing of the process cards is printed out as part of the output from the program. The process card information for the sample system shown in Figure 1 is listed in Table 3.

The FORTRAN format for the input data can be input in two ways. The first is for both a single design case and multiple design cases, where each design case has a different flow diagram. The second arrangement is used for multiple design cases that all utilize the same flow diagram. The second arrangement simplifies the preparation of input data.

Single Design Case

Table 4 gives Arrangement 1 of the FORTRAN format for reading the input data to the program. Input card 1 tells the program how many data cases (NCASE) are to be run (columns 1 and 2). In addition, REPEAT = "0" in column 4 indicates that each design case will have a different flow diagram. REPEAT = "1" in column 4 indicates that the original flow diagrem is repeated in each design case. Repeat is usually "0" in Arrangement 1. CHECK1 = "1" in column 6 causes the raw sewage composition and process design criteria to be printed out at the beginning of the first iteration. It is used for trouble shooting when one or more of the subroutines produces an overflow calculation error. CHECK1 is usually set equal to zero "0" in column 6 to avoid excess printout.

Input card 2 is the title card for each data case. Any alpha-numeric identifying data may be punched anywhere on this card, and this information will be the title of the program printout.

Input cards 3, 4 and 5 give the composite flow and concentrations of the raw sewage input stream to the treatment plant which is always labeled as Stream 1. Input cards 6 and 7 provide the general cost information. This is stored in column 20 of the decision matrix (DMATX).

The next input cards represent the processes. Each process will have three cards, unless the process number is "0" (SPLIT and/or MIX). The three cards will consist of a process card (card 8 in Table 4) and two decision cards (where necessary, cards 9 and 10 in Table 4). The last card in the data deck has a "9" in column 1. No other data is punched on the termination card. This last card is important because it indicates end-of-file for each data case. Note that the value of K in column 1

```
                           EXECUTIVE
                    DIGITAL COMPUTER PROGRAM
                              FOR
          PRELIMINARY DESIGN OF WASTEWATER TREATMENT SYSTEMS

                               BY
                          ROBERT SMITH
                        RICHARD G. EILERS

                U.S. ENVIRONMENTAL PROTECTION AGENCY
               MUNICIPAL ENVIRONMENTAL RESEARCH CENTER
                   WASTEWATER RESEARCH DIVISION
               TECHNOLOGY DEVELOPMENT SUPPORT BRANCH
               SYSTEMS AND ECONOMIC ANALYSIS SECTION
                     CINCINNATI, OHIO    45268

                         (513) 684-7618


DESIGN CASE NO. 1


10 MGD     EXECUTIVE PROGRAM STANDARD TEST SYSTEM 1    10-28-1976   JAN 1975 $$$

                             SYSTEM DIAGRAM
                               INPUT DATA

    K       N      PROCESS            IS1        IS2        OS1        OS2

    0       1     15   RWP             1          0          2          0
    0       2      1   PREL            2          0          3          0
    0       0      4   MIX             3         14          4          0
    0       3      2   PRSET           4          0          5          7
    0       4      3   AERFS           5          0          6          8
    0       0      5   SPLIT           6          0         25         24
    0       0      4   MIX             7          8          9          0
    0       5      8   THICK           9         24         10         20
    0       6      6   DIG            10          0         11          0
    0       7     21   DIG2           11          0         12         21
    0       8     16   SHT            12          0         13          0
    0       9      7   VACF           13          0         14         23
    0       0      4   MIX            20         21         22          0
    0       0      4   MIX            22         23         19          0
    0      10     14   MHINC          14          0         15          0
    0      11     12   CHLOR          25          0         26          0
    9       0      0                   0          0          0          0
```

Table 3 Sample output of process information

Input Card 1:	NCASE, REPEAT, CHECK1 FORMAT (3I2)
Input Card 2:	LIST FORMAT (40A2)
Input Cards 3, 4, 5:	(SMATX(I,1), I = 2,20) FORMAT (8F10.0)
Input Cards 6, 7:	(DMATX(I,20), I = 1,16) FORMAT (8F10.0)
Input Card 8:	K,N,IPROC,(NAME(I), I = 1,3), IS1,IS2,OS1,OS2 FORMAT (I1,1X,I2,2X,I2,1X,3A2, 4X,I2,8X,I2,8X,I2,8X,I2)
Input Cards 9, 10:	(DMATX(I,N), I = 1,16) FORMAT (8F10.0)
Input Cards 11 and on:	Continue with additional process cards. Process card with a "9" in column 1 indicates end-of-file. Begin next data case with Input Card 2, etc.

Table 4 Arrangement 1 of Fortran format for input data cards

of each process Identification Card, e.g. 8, 11, 14, etc., should be zero "0" except for the termination card.

Multiple Design Cases

Table 5 gives Arrangement 2 of the FORTRAN format for reading multiple input data to the program. On the first input card a value of one for REPEAT (a "1" in column 4) indicates that the multiple design cases will repeat, or utilize the flow diagram used in the original design case. A "0" in column 4 indicates that the original flow diagram is not being repeated, which in essence, is the format of Arrangement 1. CHECK1 can have a value of "0" in column 6. A "1" causes a printout of raw sewage composition and process design criteria to be printed out at the beginning of the first iteration. A value of "0" eliminates this initial printout.

Input cards 2 through M use the same format as in Arrangement 1.

Rather than repunch all M cards for a second (or multiple design case, a simplified, easy to punch format can be followed. Card M+1 indicates whether new raw sewage composition, SMATX (I,1), and/or new cost parameters, DMATX(I,20), and/or new process design criteria, DMATX(I,N) will be used. A value of "1" for NEWRAW in column 2, NEWCOS in column 4 and/or NEWDMX in column 6 indicates that new values are to be added in that category. A value of "0" indicates no new values will be added. Input card M+2 is the title. Beginning with input card M+3 are several possible cards. First, three SMATX(I,1) cards will follow if NEWRAW has a value of "1" rather than "0". Two DMATX(I,20) cards will then follow if NEWCOS has a value of "1" rather than "0". Finally, a series of cards will follow to indicate which processes are to have new design values, and what the new values should be. This of course is for the case where NEWDMX has a value of "1". On the next card NPROC indicates how many of the original processes will have new design criteria added. The value for NPROC is entered in columns 1 and 2 (right-justified). PROC(II) is an array which contains the user assigned number for each of the processes which will be given new design criteria. Finally, there will be two additional design criteria DMATX(I,N) cards for each of the NPROC processes being updated.

In Arrangement 2 a card with a "9" in column 1 is not placed at the end of design case 2, 3, etc. because it is not needed. Also, if three or more design cases are to be evaluated using Arrangement 2, the input cards should repeat the format of input cards M+1 through M+3 etc. for each new design case.

OUTPUT

Sample output from the program is shown in Tables 3 and 6

Input Card 1	NCASE, REPEAT, CHECK1 FORMAT (3I2)
Input Card 2	LIST FORMAT (40A2)
Input Cards 3, 4, 5	(SMATX(I,1), I = 2,20) FORMAT (8F10.0)
Input Cards 6,7	(DMATX(I,20), I = 1,16) FORMAT (8F10.0)
Input Card 8	K,NIPROC,(NAME(I), I = 1,3), IS1, IS2,OS1,OS2 FORMAT (I1,1X,I2,2X,I2,1X,3A2, 4X,I2,8X,I2,8X,I2,8X,I2)
Input Cards 9, 10	(DMATX(I,N), I = 1,16) FORMAT (8F10.0)
Input Cards 11 through M	Continue with additional process cards. Card M will be the design case termination card with a(9) in column(1). The Repeat of the same design flow diagram with different raw sewage stream characteristics, SMATX(I,1), cost parameters DMATX(I,20) and/or process design criteria DMATX(I,N) begins with the next card
Input Card M+1	NEWRAW, NEWCOS, NEWDMX FORMAT (3I2)
Input Card M+2	LIST FORMAT (40A2)

Table 5 Arrangement 2 of Fortran format for input data cards

Input Card M+3	(SMATX(I,1), I = 2,20) FORMAT (8F10.0)	only if new raw sewage characteristics will be added
	and/or	
	(DMATX(I,20) I = 1,16) FORMAT (8F10.0)	will then follow if new cost parameters will be added
	and/or	
	NPROC, (PROCNO(II), II = 1, NPROC) FORMAT (10I2)	will then follow if new process design criteria will be added for one or more of the original processes
	(DMATX(I,N) I = 1,16) FORMAT (8F10.0)	will then follow for each process which will be given new process design criteria

For repeated design cases which use the same flow diagram as the original design case, a termination card is not used. For each additional repeated design case, the sequence of input cards M+1, M+2, M+3 etc. is repeated.

Table 5 (continued)

```
                                    STREAM CHARACTERISTICS

                                                             VOLUME FLOW, MILLIONS OF GALLONS PER DAY
                                                             CONCENTRATIONS, MILLIGRAMS PER LITER

S 1.         Q          SOC        SNBC        SON         SOP         SFM        SBOD        VSS         NH3
          10.000      105.000     30.000      10.000      2.000      30.000     140.000     224.000      15.000
            ALK         DOC        DNBC         DN          DP         DFM        DBOD        TSS         NO3
          250.000      43.000     11.000      19.000      4.000     500.000      60.000     254.000        .000

S 2.         Q          SOC        SNBC        SON         SOP         SFM        SBOD        VSS         NH3
          10.000      105.000     30.000      10.000      2.000      30.000     140.000     224.000      15.000
            ALK         DOC        DNBC         DN          DP         DFM        DBOD        TSS         NO3
          250.000      43.000     11.000      19.000      4.000     500.000      60.000     254.000        .000

S 3.         Q          SOC        SNBC        SON         SOP         SFM        SBOD        VSS         NH3
          10.000      105.000     30.000      10.000      2.000      30.000     140.000     224.000      15.000
            ALK         DOC        DNBC         DN          DP         DFM        DBOD        TSS         NO3
          250.000      43.000     11.000      19.000      4.000     500.000      60.000     254.000        .000

S 4.         Q          SOC        SNBC        SON         SOP         SFM        SBOD        VSS         NH3
          12.264       96.539     31.693       9.340      1.787      31.491     121.098     208.103      15.000
            ALK         DOC        DNBC         DN          DP         DFM        DBOD        TSS         NO3
          267.645      38.117     11.000      23.530      5.079     500.000      50.839     239.594        .000

S 5.         Q          SOC        SNBC        SON         SOP         SFM        SBOD        VSS         NH3
          12.249       48.330     15.866       4.676       .895      15.765      60.625     104.182      15.000
            ALK         DOC        DNBC         DN          DP         DFM        DBOD        TSS         NO3
          267.645      38.117     11.000      23.530      5.079     500.000      50.839     119.947        .000

S 6.         Q          SOC        SNBC        SON         SOP         SFM        SBOD        VSS         NH3
          11.983        6.044      1.832        .712       .060       1.725       7.986      14.386      15.000
            ALK         DOC        DNBC         DN          DP         DFM        DBOD        TSS         NO3
          267.645      13.651     11.000      21.697      5.422     500.000       4.958      16.110        .000

S 7.         Q          SOC        SNBC        SON         SOP         SFM        SBOD        VSS         NH3
            .015    38615.554  12677.282    3736.050    714.860  12596.289   48439.362   83241.124      15.000
            ALK         DOC        DNBC         DN          DP         DFM        DBOD        TSS         NO3
          267.645      38.117     11.000      23.530      5.079     500.000      50.839   95837.414        .000
```

Table 6 Sample output of stream characteristics

```
S 8.        Q        SOC       SNBC        SON        SOP         SFM        SBOD         VSS          NH3
         .265   2276.345    689.802    268.169     22.763     649.528    3007.512    5417.702      15.000
          ALK        DOC       DNBC         DN         DP         DFM        DBOD         TSS          NO3
      267.645     13.651     11.000     21.697      5.422     500.000       4.958    6067.230        .000

S 9.        Q        SOC       SNBC        SON        SOP         SFM        SBOD         VSS          NH3
         .281   4260.209   1344.234    457.491     60.547    1301.736    5487.770    9666.310      15.000
          ALK        DOC       DNBC         DN         DP         DFM        DBOD         TSS          NO3
      267.645     14.987     11.000     21.798      5.403     500.000       7.463   10968.046        .000

S10.        Q        SOC       SNBC        SON        SOP         SFM        SBOD         VSS          NH3
         .059  19414.194   6123.395   2086.842    275.106    5928.239   25014.690   44071.760      15.000
          ALK        DOC       DNBC         DN         DP         DFM        DBOD         TSS          NO3
      267.645     13.817     11.000     21.710      5.419     500.000       5.268   50000.000        .000

S11.        Q        SOC       SNBC        SON        SOP         SFM        SBOD         VSS          NH3
         .059   6468.503   6123.395    708.346     93.380    5928.239     645.353   15395.037      15.000
          ALK        DOC       DNBC         DN         DP         DFM        DBOD         TSS          NO3
     3466.444    126.036     11.000    917.732    187.145     500.000     215.118   21323.276        .000

S12.        Q        SOC       SNBC        SON        SOP         SFM        SBOD         VSS          NH3
         .020  15167.705  14358.475   1660.970    218.964   13900.863    1513.259   36099.137      15.000
          ALK        DOC       DNBC         DN         DP         DFM        DBOD         TSS          NO3
     3466.444    126.036     11.000    917.732    187.145     500.000     215.118   50000.000        .000

S13.        Q        SOC       SNBC        SON        SOP         SFM        SBOD         VSS          NH3
         .020  15167.705  14358.475   1660.970    218.964   19725.863    1513.259   36099.137      15.000
          ALK        DOC       DNBC         DN         DP         DFM        DBOD         TSS          NO3
     3466.444    126.036     11.000    917.732    187.145     500.000     215.118   55825.000        .000

S14.        Q        SOC       SNBC        SON        SOP         SFM        SBOD         VSS          NH3
         .004  78186.274  74014.870   8561.944   1128.710  101682.606    7800.527  186083.332      15.000
          ALK        DOC       DNBC         DN         DP         DFM        DBOD         TSS          NO3
    17868.779    649.689     56.703   4730.712    964.690    2577.393    1108.885  287765.941        .000

S15.        Q        SOC       SNBC        SON        SOP         SFM        SBOD         VSS          NH3
         .000       .000       .000       .000       .000        .000        .000        .000        .000
          ALK        DOC       DNBC         DN         DP         DFM        DBOD         TSS          NO3
         .000       .000       .000       .000       .000        .000        .000        .000        .000
```

Table 6 (continued)

```
S19.        Q        SOC       SNBC       SON       SOP       SFM      SBOD       VSS       NH3
        2.264     59.171     39.171     6.426      .847    38.074    37.621   137.894    15.000
          ALK        DOC       DNBC        DN        DP       DFM      DBOD       TSS       NO3
      345.575     16.551     11.000    43.539     9.846   500.000    10.381   175.969      .000

S20.        Q        SOC       SNBC       SON       SOP       SFM      SBOD       VSS       NH3
        2.209     27.349      8.626     2.940      .388     8.351    35.238    62.084    15.000
          ALK        DOC       DNBC        DN        DP       DFM      DBOD       TSS       NO3
      267.645     13.817     11.000    21.710     5.419   500.000     5.268    70.435      .000

S21.        Q        SOC       SNBC       SON       SOP       SFM      SBOD       VSS       NH3
         .039   1877.612   1777.438   205.612    27.106  1720.790   187.327  4469.718    15.000
          ALK        DOC       DNBC        DN        DP       DFM      DBOD       TSS       NO3
     3466.444    126.036     11.000   917.732   187.145   500.000   215.118  6189.508      .000

S22.        Q        SOC       SNBC       SON       SOP       SFM      SBOD       VSS       NH3
        2.248     59.206     39.081     6.429      .848    37.836    37.857   137.957    15.000
          ALK        DOC       DNBC        DN        DP       DFM      DBOD       TSS       NO3
      322.722     15.749     11.000    37.137     8.548   500.000     8.882   175.793      .000

S23.        Q        SOC       SNBC       SON       SOP       SFM      SBOD       VSS       NH3
         .016     54.340     51.441     5.951      .784    70.670     5.421   129.330    15.000
          ALK        DOC       DNBC        DN        DP       DFM      DBOD       TSS       NO3
     3466.444    126.036     11.000   917.732   187.145   500.000   215.118   200.000      .000

S24.        Q        SOC       SNBC       SON       SOP       SFM      SBOD       VSS       NH3
        1.987      6.044      1.832      .712      .060     1.725     7.986    14.386    15.000
          ALK        DOC       DNBC        DN        DP       DFM      DBOD       TSS       NO3
      267.645     13.651     11.000    21.697     5.422   500.000     4.958    16.110      .000

S25.        Q        SOC       SNBC       SON       SOP       SFM      SBOD       VSS       NH3
        9.996      6.044      1.832      .712      .060     1.725     7.986    14.386    15.000
          ALK        DOC       DNBC        DN        DP       DFM      DBOD       TSS       NO3
      267.645     13.651     11.000    21.697     5.422   500.000     4.958    16.110      .000

S26.        Q        SOC       SNBC       SON       SOP       SFM      SBOD       VSS       NH3
        9.996      6.044      1.832      .712      .060     1.725     7.986    14.386    15.000
          ALK        DOC       DNBC        DN        DP       DFM      DBOD       TSS       NO3
      267.645     13.651     11.000    21.697     5.422   500.000     4.958    16.110      .000
```

Table 6 (continued)

```
                              PROCESS CHARACTERISTICS

                                              CCOST = CAPITAL COST, DOLLARS
                                              COSTO = OPERATING + MAINTENANCE COST, CENTS/1000 GAL.
                                              ACOST = AMORTIZATION COST, CENTS/1000 GAL.
                                              TCOST = TOTAL TREATMENT COST, CENTS/1000 GAL.

P 1  RAW WASTEWATER   HEAD       GP                                              CCOST     COSTO     ACOST     TCOST      ECF
     PUMPING          30.00    14.81                                           710223.      .520     1.522     2.042     1.00

P 2  PRELIMINARY    IPREL                                                        CCOST     COSTO     ACOST     TCOST      ECF
     TREATMENT        1.0                                                      216086.      .569      .463     1.032     1.00

P 3  PRIMARY         FRPS      URPS      HPWK       GPS       APS       PGPM
     SEDIMENTATION    .50     400.0      14.0    1375.2    10.701       128.

                                                                         CCOST     COSTO     ACOST     TCOST      FCF
                                                             SETTLER   312019.      .276      .669      .945     1.20

                                                             SLUDGE     95348.      .308      .204      .512     1.00
                                                             PUMPS

P 4  ACTIVATED SLUDGE-  BOD      MLSS      DEGC    CAER20        DO    AEFF20      URSS       GSS      HEAD      ALMD
     FINAL SETTLER     13.0     2000.     20.00      1.00      1.00       .05      3.00    700.00     30.00       .00

                       BOD2     DOSAT      XRSS       AFS      CAER      CEDR      VAER      VNIT     MLASS     MLBSS
                      111.5      10.8     .0080     20.54      1.00      .125     2.319     3.648      248.     1041.

                     MLNBSS     MLDSS     MLISS      FOOD     RTURN      CNIT     ARCFD     BSIZE     CFPGL        QR
                       464.       30.      217.      45.9      .464      .321  4153202.     2884.       .34     5.679

                                                                         CCOST     COSTO     ACOST     TCOST      ECF
                                                             AERATOR   600279.      .000     1.287     1.287     1.20

                                                             BLOWER    254571.      .951      .546     1.497     1.00

                                                             SLUDGE    160196.      .349      .343      .693     1.00
                                                             PUMPS

                                                             FINAL     506368.      .422     1.085     1.507     1.20
                                                             SETTLER
```

Table 7 Sample output of process characteristics

```
P 5  GRAVITY               TRR       TSS       GTH      GSTH      ATHM       WRT
     THICKENING            .95    50000.     700.0       8.0    4860.5      7.08

                                                                           CCOST     COSTO     ACOST     TCOST       ECF
                                                                         185807.      .153      .398      .551      1.50

P 6  SINGLE STAGE           TD      TDIG     C1DIG     C2DIG      VDIG       CH4       CO2
     ANAEROBIC            15.0      30.0      .234     1154.   154.143   124331.    65296.
     DIGESTION
                                                                           CCOST     COSTO     ACOST     TCOST       ECF
                                                                         624828.      .410     1.339     1.749      1.30

P 7  SECOND STAGE          TRR       TSS        TD      VDIG                 CCOST     COSTO     ACOST     TCOST       ECF
     ANAEROBIC             .81    50000.      15.0   118.571               521959.      .410     1.119     1.529      1.00
     DIGESTION

P 8  SLUDGE HOLDING         TD      VSHT                                     CCOST     COSTO     ACOST     TCOST       ECF
     TANKS                15.0      41.0                                   188161.      .272      .403      .675      1.00

P 9  VACUUM                VFL      HPWK       TSS     IVACF     FECL3       CAO     CFECL      CCAO     DPOLY     CPOLY
     FILTRATION           4.90       35.      200.       1.0     42.00    176.00     .0640     .0125     15.00     .3300

                            WP       AVF      PSDD                         CCOST     COSTO     ACOST     TCOST       ECF
                          71.2     671.1     9498.                       960780.     1.384     2.059     3.443      1.00

P10  MULTIPLE HEARTH        ML      NINC      HPWK      SPER        WV        HV      TYPE        FC       CNG
     INCINERATION          2.0       1.0      35.0       5.0        .0   10000.0       1.0      .300      .970

                           FHA      WFYR      PSDD     ECOST     FCOST
                          988.   290968.     9505.     1637.    11668.

                                                                           CCOST     COSTO     ACOST     TCOST       ECF
                                                                         773168.      .935     1.657     2.592      1.00

P11  CHLORINATION-        DCL2      TCL2      CCL2      DSO2      CSO2      BVOL      CUSE      SUSE
     DECHLORINATION       8.00      30.0    220.00      2.50    180.00    41762.    121.57     37.99

                                                                           CCOST     COSTO     ACOST     TCOST       ECF
                                                         CONTACT         129678.      .000      .278      .278      1.50
                                                         BASIN
```

Table 7 (continued)

```
                                                CL2 FEED   106436.      .983      .228     1.211      1.20
                                                SYSTEM

                                                SO2 FEED    33261.      .266      .071      .337      1.20
                                                SYSTEM

ADMINISTRATIVE                                             CCOST      COSTO     ACOST     TCOST
AND LABORATORY                                             221023.     .572      .474     1.045

GARAGE                                                     CCOST      COSTO     ACOST     TCOST
AND SHOP                                                    65407.     .000      .140      .140

LABORATORY        XLAB                                     CCOST      COSTO     ACOST     TCOST
OPERATION          1.0                                         0.      .646      .000      .646

YARDWORK                                                   CCOST      COSTO     ACOST     TCOST
OPERATION                                                      0.      .354      .000      .354
```

Table 7 (continued)

```
                         TOTAL PLANT COST

          TOTAL CAPITAL COST =  6665598. DOLLARS                TOT
     TOTAL AMORTIZATION COST =    14.286 CENTS/1000 GALLONS     TAMM
            TOTAL O + M COST =     9.778 CENTS/1000 GALLONS     TOPER
        TOTAL TREATMENT COST =    24.064 CENTS/1000 GALLONS     TOTAL


   CCI      WPI      RI       YRS      DHR      PCT      DA       CCINT     XLAR      CKWH
   2.257    1.675    .060     25.0     4.73     .150     1000.      .06      1.00      .020

 RATIO      TCAP     YARD      TCC     XLAND     ENG      SUBT1     FISC     SUBT2     XINT
   1.331  5008960.  701254.  5710214.   19977.  470179.  6200370.   39740.  6240110.  425488.
  ACRE       AF
   19.96   .07823
```

Table 8 Output showing total plant cost

```
                         ENERGY CONSUMPTION AND COST

   10.00   10.00   10.00   10.00   10.00   10.00   10.00   10.00   10.00   10.00   10.00   10.00
   10.00   10.00   10.00   10.00   10.00   10.00   10.00   10.00   10.00   10.00   10.00   10.00
   10.00

   15.00    1.00    2.00    3.00    8.00    6.00   21.00   16.00    7.00   14.00   12.00     .00
     .00     .00     .00     .00     .00     .00     .00     .00     .00     .00     .00     .00
   25.00

 1450.31   66.37  107.30 5875.37   20.42  453.30  453.30     .00  352.17  245.25     .72     .00
     .00     .00     .00     .00     .00     .00     .00     .00     .00     .00     .00     .00
  210.23

 9234.74
```

Table 9 Output showing energy consumption and cost

through 9 for the example wastewater treatment system. For a particular design case, the first group of output shows the title of system and the process cards which describe the simulated wastewater treatment system (see Table 3). The second group of output data (Table 6) shows the volume flow and concentrations of the 17 contaminants in each numbered stream. The stream is identified by the letter S followed by the number in the left-hand column of the printout. For example, stream number 3 is identified by S3. The third part of the output (Table 7) lists the unit processes according to process number and gives the name of the process with all pertinent input and output parameters and cost data relating to the process. The process is identified by the letter P followed by the process number in the left hand column of the printout. For example, process number 3 identified by P3. The fourth set of printout (Table 8) gives the total costs for the entire plant and general items relating to the cost calculations. The fifth and final part of the printout (Table 9) gives the energy requirements of the unit processes used. The electrical power, natural gas, fuel oil, gasoline, etc., required for operation of the plant are converted to British Thermal Units (BTU). This conversion provides an easy means to compare total energy use for alternate treatment systems.

A flow chart of EXECMAIN is shown in Figure 2. The chart shows the major branches and loops in the program.

Discussion of individual process subroutines used in conjunction with EXECMAIN is found in the following sections.

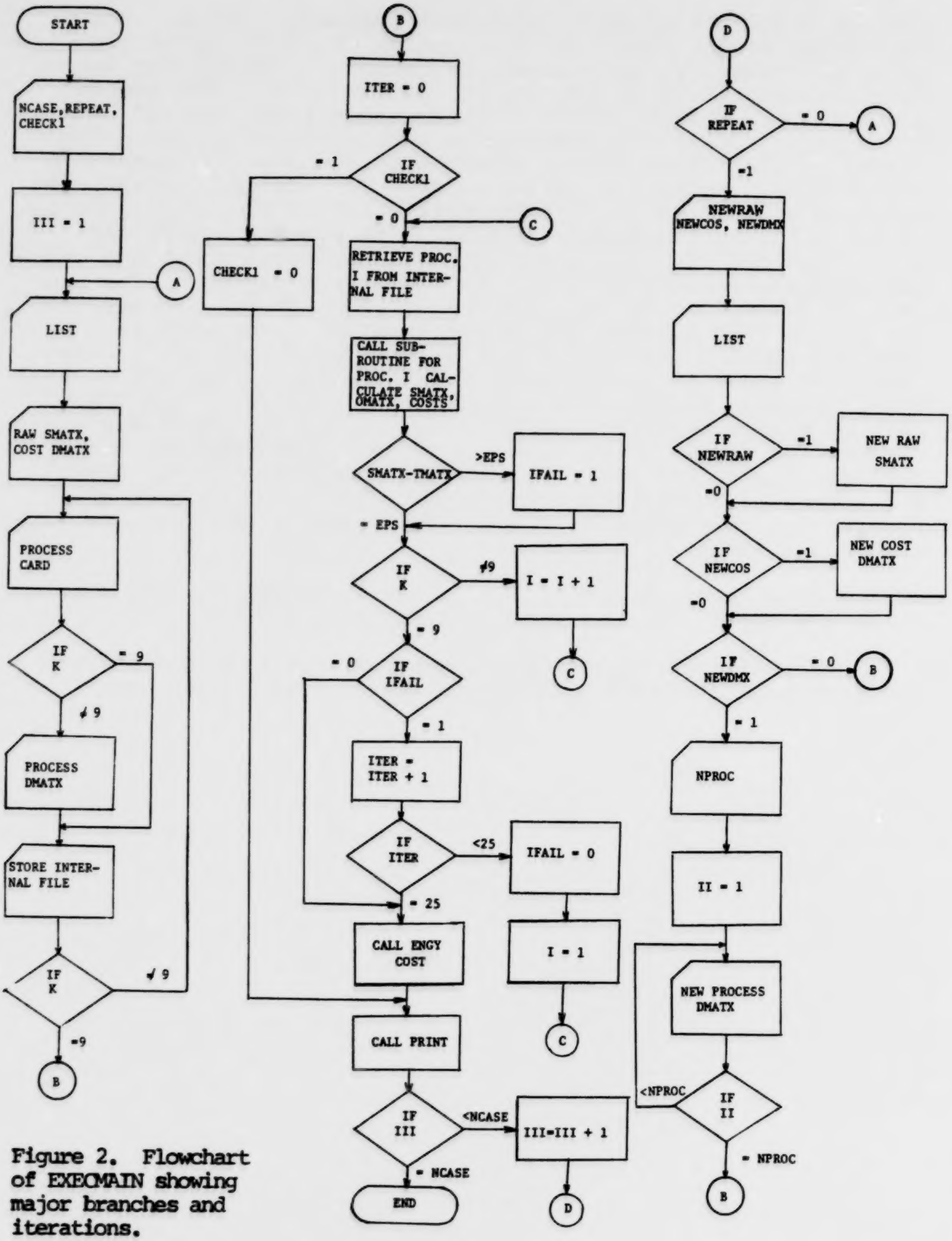

START
NCASE,REPEAT,
CHECK1
III = 1
A
LIST
RAW SMATX,
COST DMATX
PROCESS
CARD
IF
K
= 9
≠ 9
PROCESS
DMATX
STORE INTER-
NAL FILE
IF
K
≠ 9
=9
B
B
ITER = 0
IF
CHECK1
= 1
= 0
CHECK1 = 0
C
RETRIEVE PROC.
I FROM INTER-
NAL FILE
CALL SUB-
ROUTINE FOR
PROC. I CAL-
CULATE SMATX,
OMATX, COSTS
SMATX-TMATX
>EPS
IFAIL = 1
= EPS
IF
K
≠9
I = I + 1
C
= 9
IF
IFAIL
= 0
= 1
ITER =
ITER + 1
IF
ITER
<25
IFAIL = 0
I = 1
C
= 25
CALL ENGY
COST
CALL PRINT
IF
III
<NCASE
III=III + 1
D
= NCASE
END
D
IF
REPEAT
= 0
A
=1
NEWRAW
NEWCOS, NEWDMX
LIST
IF
NEWRAW
=1
NEW RAW
SMATX
=0
IF
NEWCOS
=1
NEW COST
DMATX
=0
IF
NEWDMX
= 0
B
= 1
NPROC
II = 1
NEW PROCESS
DMATX
IF
II
<NPROC
= NPROC
B

Figure 2. Flowchart of EXECMAIN showing major branches and iterations.

```
C             EXECMAIN                                                  EXE00100
C             EXECUTIVE PROGRAM FOR DESIGN OF WASTEWATER TREATMENT PLANTEXE00200
C             RICHARD G. EILERS, ROBERT SMITH AND ILLINOIS INSTITUTE    EXE00300
C             OF TECHNOLOGY, ENVIRONMENTAL ENGINEERING DEPARTMENT       EXE00400
C             AUG. 1977                                                 EXE00500
C                                                                       EXE00600
C                                                                       EXE00700
C             COMMON INITIAL STATEMENTS                                 EXE00800
C                                                                       EXE00900
      INTEGER OS1,OS2,REPEAT,CHECK1,PROCNO                              EXE01000
      DIMENSION NAME(3),LIST(40)                                        EXE01100
      COMMON SMATX(20,30),TMATX(20,30),DMATX(20,20),OMATX(20,20),IP(20),EXE01200
     1INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),ACOST(20,5)EXE01300
     2,TCOST(20,5),DHR,PCT,WPI,CLAND,DLAND,PROCNO(10),FLOW(25),POW(25),TEXE01400
     3KWHD(25)                                                          EXE01500
C                                                                       EXE01600
C                                                                       EXE01700
C             DEFINE AN INTERNAL FILE FOR TEMPORARY STORAGE OF PROCESS  EXE01800
C             DATA USED LATER IN THE EXECMAIN                           EXE01900
C                                                                       EXE02000
      DEFINE FILE 2(50,15,U,NNNNN)                                      EXE02100
C                                                                       EXE02200
C                                                                       EXE02300
C             ASSIGNMENT OF NUMBERS REPRESENTATIVE OF THE USERS INPUT,  EXE02400
C             INP, AND OUTPUT, IO, DEVICES                              EXE02500
C                                                                       EXE02600
      INP=5                                                             EXE02700
      IO=6                                                              EXE02800
C                                                                       EXE02900
C                                                                       EXE03000
C             INPUT   FIRST DATA CARD                                   EXE03100
C                                                                       EXE03200
      READ (INP,10) NCASE,REPEAT,CHECK1                                 EXE03300
   10 FORMAT (3I2)                                                      EXE03400
C                                                                       EXE03500
C                                                                       EXE03600
C             MAJOR LOOP FOR EACH DESIGN CASE                           EXE03700
C                                                                       EXE03800
      DO 770 III=1,NCASE                                                EXE03900
      IF (III.EQ.1) GO TO 20                                            EXE04000
      IF (REPEAT.EQ.0) GO TO 20                                         EXE04100
C                                                                       EXE04200
C                                                                       EXE04300
C             INPUT   REPEATED DESIGN CASES ONLY - REPEATED FLOW        EXE04400
C             DIAGRAM WITH NEW VALUES FOR RAW SEWAGE STREAM, COST       EXE04500
C             PARAMETERS AND/OR DESIGN MATRIX VALUES                    EXE04600
C                                                                       EXE04700
      READ (INP,10) NEWRAW,NEWCOS,NEWDMX                                EXE04800
      GO TO 50                                                          EXE04900
   20 CONTINUE                                                          EXE05000
C                                                                       EXE05100
C                                                                       EXE05200
C             INITIAL ZEROING OF ARRAYS - NOT NECESSARY IN SUBSEQUENT   EXE05300
C             DESIGN CASES WHICH USE SAME FLOW DIAGRAM                  EXE05400
C                                                                       EXE05500
      DO 30 I=1,20                                                      EXE05600
      DO 30 J=1,30                                                      EXE05700
      SMATX(I,J)=0.                                                     EXE05800
   30 CONTINUE                                                          EXE05900
      DO 40 I=1,20                                                      EXE06000
      IP(I)=0                                                           EXE06100
      DO 40 J=1,20                                                      EXE06200
      DMATX(I,J)=0.                                                     EXE06300
   40 CONTINUE                                                          EXE06400
C                                                                       EXE06500
C                                                                       EXE06600
C             INITIAL ZEROING OF ARRAYS                                 EXE06700
C                                                                       EXE06800
   50 CONTINUE                                                          EXE06900
      DO 60 I=1,25                                                      EXE07000
      FLOW(I)=0.                                                        EXE07100
      POW(I)=0.                                                         EXE07200
      TKWHD(I)=0.                                                       EXE07300
   60 CONTINUE                                                          EXE07400
      DO 70 I=1,20                                                      EXE07500
      DO 70 J=1,30                                                      EXE07600
      TMATX(I,J)=0.                                                     EXE07700
   70 CONTINUE                                                          EXE07800
      DO 80 I=1,20                                                      EXE07900
      DO 80 J=1,20                                                      EXE08000
      OMATX(I,J)=0.                                                     EXE08100
   80 CONTINUE                                                          EXE08200
      DO 90 I=1,20                                                      EXE08300
      DO 90 J=1,5                                                       EXE08400
      CCOST(I,J)=0.                                                     EXE08500
      COSTO(I,J)=0.                                                     EXE08600
      ACOST(I,J)=0.                                                     EXE08700
      TCOST(I,J)=0.                                                     EXE08800
   90 CONTINUE                                                          EXE08900
      IAERF=0                                                           EXE09000
      CLAND=0.                                                          EXE09100
      DLAND=0.                                                          EXE09200
      EPS=.1                                                            EXE09300
C                                                                       EXE09400
C                                                                       EXE09500
C             INPUT   NEW AND REPEATED DESIGN CASES                     EXE09600
C                                                                       EXE09700
      READ (INP,100) LIST                                               EXE09800
  100 FORMAT (40A2)                                                     EXE09900
      WRITE (IO,110)                                                    EXE10000
  110 FORMAT (1H1,//,55X,'EXECUTIVE',/,47X,'DIGITAL COMPUTER PROGRAM',/,EXE10100
     158X,'FOR',/,34X,'PRELIMINARY DESIGN OF WASTEWATER TREATMENT SYSTEMEXE10200
     2S',//,58X,'BY',/,53X,'ROBERT SMITH',/,51X,'RICHARD G. EILERS',/)  EXE10300
      WRITE (IO,120)                                                    EXE10400
  120 FORMAT (41X,'U.S. ENVIRONMENTAL PROTECTION AGENCY',/,39X,'MUNICIPAEXE10500
     1L ENVIRONMENTAL RESEARCH CENTER',/,45X,'WASTEWATER RESEARCH DIVISIEXE10600
     2ON',/,40X,'TECHNOLOGY DEVELOPMENT SUPPORT BRANCH',/,40X,'SYSTEMS AEXE10700
     3ND ECONOMIC ANALYSIS SECTION',/,47X,'CINCINNATI, OHIO   45268',//,EXE10800
     452X,'(513) 684-7618',/////)                                       EXE10900
      WRITE (IO,130) III                                                EXE11000
  130 FORMAT (/,20X,'DESIGN CASE NO.',I2,//)                            EXE11100
      WRITE (IO,140) LIST                                               EXE11200
  140 FORMAT (20X,40A2,//,52X,'SYSTEM DIAGRAM',/,54X,'INPUT DATA',//,28XEXE11300
     1,'K',5X,'N',5X,'PROCESS',9X,'IS1',7X,'IS2',7X,'OS1',7X,'OS2',/)   EXE11400
      IF (III.EQ.1) GO TO 150                                           EXE11500
      IF (REPEAT.EQ.1.AND.NEWRAW.EQ.0) GO TO 160                        EXE11600
  150 CONTINUE                                                          EXE11700
C                                                                       EXE11800
C                                                                       EXE11900
C             INPUT   NEW AND SOME REPEATED DESIGN CASES                EXE12000
C                                                                       EXE12100
      READ (INP,180) (SMATX(I,1),I=2,20)                                EXE12200
  160 CONTINUE                                                          EXE12300
      IF (III.EQ.1) GO TO 170                                           EXE12400
      IF (REPEAT.EQ.1.AND.NEWCOS.EQ.0) GO TO 190
  170 CONTINUE
C
C
C              INPUT   NEW AND SOME REPEATED DESIGN CASES
C
      READ (INP,180) (DMATX(I,20),I=1,16)
  180 FORMAT (8F10.0)
  190 CONTINUE
      WPI=DMATX(2,20)/1.122
      DHR=DMATX(5,20)
      PCT=DMATX(6,20)
      IF (III.EQ.1) GO TO 230
      IF (REPEAT.EQ.0) GO TO 230
      WRITE (IO,200)
  200 FORMAT (/////,40X,'PROCESS AND STREAM NUMBERING SAME AS DESIGN CAS
     1E NO. 1')
      IF (NEWDMX.EQ.0) GO TO 340
C
C
C              INPUT   SOME REPEATED DESIGN CASES ONLY - NOT FOR NEW
C              CASES
C
      READ (INP,210) NPROC,(PROCNO(II),II=1,NPROC)
  210 FORMAT (10I2)
      DO 220 II=1,NPROC
      N=PROCNO(II)
C
C
C              INPUT   SOME REPEATED DESIGN CASES ONLY - NOT FOR NEW
C              CASES
C
      READ (INP,180) (DMATX(I,N),I=1,16)
  220 CONTINUE
      GO TO 340
  230 CONTINUE
C
C
C              BEGINNING OF LOOP DOWN TO STATEMENT 340 WHICH WILL
C              ASSIGN VALUES TO EACH PROCESS, INFLUENT STREAM AND
C              EFFLUENT STREAM IN THE FLOW DIAGRAM - IF SAME FLOW
C              DIAGRAM IS USED, THIS SECTION IS SKIPPED
C
      KKK=1
  240 READ (INP,250) K,N,IPROC,(NAME(I),I=1,3),IS1,IS2,OS1,OS2
  250 FORMAT (I1,1X,I2,2X,I2,1X,3A2,4X,I2,8X,I2,8X,I2,8X,I2)
      WRITE (IO,260) K,N,IPROC,(NAME(I),I=1,3),IS1,IS2,OS1,OS2
  260 FORMAT (28X,I1,4X,I2,4X,I2,2X,3A2,7X,I2,8X,I2,8X,I2,8X,I2)
      IF (K-9) 270,330,330
  270 SMATX(1,IS1)=IS1
      SMATX(1,OS1)=OS1
      IF (IS2) 290,290,280
  280 SMATX(1,IS2)=IS2
  290 IF (OS2) 310,310,300
  300 SMATX(1,OS2)=OS2
  310 IF (N) 330,330,320
  320 IP(N)=IPROC
      READ (INP,180) (DMATX(I,N),I=1,16)
C
C
C              WRITING PROCESS AND STREAM NUMBERS ONTO THE INTERNAL
C              FILE WHICH WAS DEFINED ABOVE
C
  330 WRITE (2'KKK) K,N,IPROC,IS1,IS2,OS1,OS2
      KKK=KKK+1
      IF (K-9) 240,350,350
  340 CONTINUE
  350 ITER=0
C
C
C           BEGINNING OF ITERATIVE LOOP IN WHICH THE STREAM
C           PARAMETERS ARE REEVALUATED TO REFLECT THE EFFECT OF
C           POSSIBLE RECYCLE STREAMS BACK TO THE BEGINNING SECTIONS
C           OF THE PLANT
C
  360 ITER=ITER+1
      IF (ITER.NE.1) GO TO 370
C
C
C           INITIAL VALUES OF ALL PROCESSES AND STREAMS WILL BE
C           PRINTED IF CHECK1 IS EQUAL TO 1 - TROUBLESHOOTING AID
C           IF PROGRAM EXECUTION IS INTERRUPTED
C
      IF (CHECK1.EQ.0) GO TO 370
      CHECK1=0
      CALL PRINT
  370 CONTINUE
      KKK=1
      IFAIL=0
      IF (ITER-25) 400,400,380
  380 WRITE (10,390)
  390 FORMAT (/////,10X,'EXECUTIVE ITERATION DOES NOT CONVERGE',/,10X,'PE
     1RINTOUT IS FOR THE LAST ITERATION')
      GO TO 760
C
C
C           READING THE PROCESS AND STREAM NUMBERS STORED IN THE
C           TEMPORARY INTERNAL FILE
C
  400 READ (2'KKK) K,N,IPROC,IS1,IS2,OS1,OS2
      KKK=KKK+1
C
C
C           AFTER ALL PROCESSES HAVE BEEN CALCULATED FOR THE FIRST
C           ITERATION AND THE NEXT PROCESS DATA TO BE READ FROM
C           THE INTERNAL FILE IS THE ONE WITH THE LONE VALUE OF
C           K=9 IN COL. 1., IFAIL WILL BE EQUAL TO 1 AND STATEMENT
C           410 WILL BE EXECUTED
C
      IF (K-9) 420,410,410
C
C
C           WHEN IFAIL=1, CONTROL WILL SHIFT TO STATEMENT 360 WHICH
C           LEADS TO THE INCREMENTATION OF ITER AND RESETTING
C           IFAIL=0 - A SECOND, THIRD, FOURTH,...NTH... ITERATION
C           WHERE ALL THE PROCESSES WILL BE CALCULATED WILL FOLLOW
C           - EVENTUALLY TWO COMPLETE ITERATIONS WOULD BE CALCULATED
C           WITHOUT IFAIL BEING SET EQUAL TO 1 BY STATEMENT 710 -
C           CONTROL WILL THEN SHIFT TO STATEMENT 760 FOR THE
C           BEGINNING OF A NORMAL TERMINATION OF THE DESIGN CASE
C
  410 IF (IFAIL) 760,760,360
  420 GO TO (430,440,450,460,470,480,490,500,510,520,530,540,550,560,570
     1,580,590,600,610,620,630,640,650,660), IPROC
  430 CALL PREL
      GO TO 670
  440 CALL PRSET
      GO TO 670
  450 CALL AERFS
C
C
C            IF THE REQUIRED MLASS, BOD5 OR MLSS CAN NOT BE ATTAINED
```

```
C             IN THE AERFS SUBROUTINE, IAERF WILL BE RETURNED FROM
C             AERFS WITH A VALUE OF 1 (ONE) - THIS TRANSFER CONTROL
C             TO STATEMENT 760 WHICH WILL TERMINATE THE DESIGN CASE
C
      IF (IAERF) 670,670,760
  460 CALL MIX
      GO TO 670
  470 CALL SPLIT
      GO TO 670
  480 CALL DIG
      GO TO 670
  490 CALL VACF
      GO TO 670
  500 CALL THICK
      GO TO 670
  510 CALL ELUT
      GO TO 670
  520 CALL SBEDS
      GO TO 670
  530 CALL TRFS
      GO TO 670
  540 CALL CHLOR
      GO TO 670
  550 CALL TFLOT
      GO TO 670
  560 CALL MHINC
      GO TO 670
  570 CALL RWP
      GO TO 670
  580 CALL SHT
      GO TO 670
  590 CALL CENT
      GO TO 670
  600 CALL AEROB
      GO TO 670
  610 CALL POSTA
      GO TO 670
  620 CALL EQUAL
      GO TO 670
  630 CALL DIG2
      GO TO 670
  640 CALL LANDD
      GO TO 670
  650 CALL LIME
      GO TO 670
  660 CALL RBC
C
C
C             CHECK IF DIFFERENCE BETWEEN LATEST STREAM VALUES,
C             SMATX(I,OS1), AND PREVIOUS STREAM VALUES, TMATX(I,OS1),
C             IS LESS THAN THE ALLOABLE ERROR, EPS, IN MG/L - IF NOT,
C             SET THE ITERATION ERROR TEST PARAMETER IFAIL=1 AND
C             CONTINUE THE ITERATIVE EFFORT TO REFINE THE STREAM
C             PARAMETER VALUES - IF LESS THAN OR EQUAL TO ALLOWABLE
C             ERROR, CHECK THE STREAM PARAMETERS FOR OS2
C
  670 DO 680 I=2,20
      IF (ABS(SMATX(I,OS1)-TMATX(I,OS1))-EPS) 680,680,710
  680 CONTINUE
      IF (OS2) 720,720,690
C
C
C             CHECK PARAMETERS FOR OS2 - IF GREATER THAN ALLOWABLE
C             ERROR, SET THE ITERATION ERROR TEST PARAMETER IFAIL=1
C             AND CONTINUE THE ITERATIVE EFFORT TO REFINE THE STREAM
C             PARAMETER VALUES - IF LESS THAN OR EQUAL TO ALLOWABLE
```

```
C             ERROR, REPLACE THE PREVIOUS STREAM VALUES, TMATX, WITH     EXE32300
C             THE LATEST STREAM VALUES, SMATX                            EXE32400
C                                                                        EXE32500
  690 DO 700 I=2,20                                                      EXE32600
      IF (ABS(SMATX(I,OS2)-TMATX(I,OS2))-EPS) 700,700,710                EXE32700
  700 CONTINUE                                                           EXE32800
      GO TO 720                                                          EXE32900
  710 IFAIL=1                                                            EXE33000
  720 DO 730 I=1,20                                                      EXE33100
      TMATX(I,OS1)=SMATX(I,OS1)                                          EXE33200
  730 CONTINUE                                                           EXE33300
      IF (OS2) 400,400,740                                               EXE33400
  740 DO 750 I=1,20                                                      EXE33500
      TMATX(I,OS2)=SMATX(I,OS2)                                          EXE33600
  750 CONTINUE                                                           EXE33700
      GO TO 400                                                          EXE33800
  760 CALL ENGY                                                          EXE33900
      CALL COST                                                          EXE34000
      CALL PRINT                                                         EXE34100
  770 CONTINUE                                                           EXE34200
      END                                                                EXE34300
```

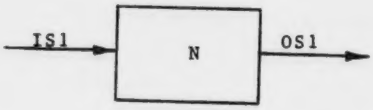
SECTION 2

PRELIMINARY TREATMENT, PREL

Subroutine Identification Number 1

Preliminary Treatment, PREL Rev. Date 8/1/77

1. Process symbol.



IS1: Liquid input stream

OS1: Liquid output stream

N: User assigned number to the process

2. Input parameters and nominal values.

DMATX(1,N) = IPREL	Program control number: 0 = grit removal and flow measurement; 1 = grit removal and flow measurement and screening. [1.]
DMATX(16,N) = ECF	Excess capacity factor for the process.

3. Output parameters which are printed on computer output sheets.

IPREL = DMATX(1,N)

CCOST = Capital cost,(dollars).

COSTO = Operating and maintenance cost,(cents/1000 gal).

ACOST = Amortization cost,(cents/1000 gal).

TCOST = Total treatment cost ,(cents/1000 gal) .

ECF = Excess capacity factor.

4. Theory and functions - FORTRAN statement followed by equivalent algebraic equation.

```
SMATX(I,OS1) = SMATX(I,IS1)                                    PRE02400
```

SMATX(I,OS1) = SMATX(I,IS1) [mg/l]

I = 2,20 Q,SOC,SNBC,SON,SOP,SFM,SBOD,VSS,TSS,DOC,DNBC,DN,DP,DFM,ALK,DBOD,NH3,NO3

```
IPREL = DMATX(1,N)                                                   PRE01800
```

$$IPREL = DMATX(1,N)$$

References: Smith, 1969

Patterson and Banker, 1971

5. Cost functions.

a. Capital cost

Function of Q_{IS1}*ECF

```
X = ALOG(SMATX(2,IS1)*DMATX(16,N))                                   PRE03000
```

$$X = \ln(Q_{IS1}*ECF)$$

(1) For preliminary treatment consisting of grit removal and flow measurement

```
CCOST(N,1) = EXP(2.566569+.619151*X)*1000.                           PRE03700
```

$$CCOST = 1000e^{2.566569+0.619151X} \quad [\text{dollars}]$$

(2) For preliminary treatment consisting of grit removal, flow measurement and screening

```
CCOST(N,1) = EXP(3.259716 +.619151*X)*1000.                          PRE04500
```

$$CCOST = 1000e^{3.259716+.619151*X} \quad [\text{dollars}]$$

b. Operating manhours, maintenance manhours, and materials/supplies costs

Function of Q_{IS1}

```
X = ALOG(SMATX(2,IS1))                                               PRE05100
```

$$X = \ln(Q_{IS1})$$

(1) Operating manhours

```
OHRS = EXP(6.398716+.230956*X+.164959*X**2.-.014601*X**3.)          PRE05700
```

$$OHRS = e^{6.398716+.230956*X+.164959*X^2-.014601*X^3} \quad [\text{hrs/yr}]$$

(2) Maintenance manhours

```
XMHRS = EXP(5.846098+.206513*X+.068842*X**2+.023824*X**3.-.004410*X**4.) PRE05800
```

$$XMHRS = e^{5.846098+.206513*X+.068842*X^2+.023824*X^3-.004410*X^4} \quad [\text{hrs/yr}]$$

(3) Total materials and supplies

```
TMSU = EXP(7.235657+.399935*X-.224979*X**2.+.110099*X**3.-.011026*X**4.) PRE06000
```

$$TMSU = e^{7.235657+.399935*X-.224979*X^2+.110099*X^3-.011026*X^4} \quad [\$/yr]$$

c. Total operating and maintenance costs

```
COSTO(N,1) = ((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.          PRE06600
```

$$COSTO = \frac{(OHRS+XMHRS)*DHR*(1+PCT)+TMSU*WPI}{Q_{Plant\ Inf.} * 3650} \quad [cents/1000\ gal]$$

Cost curves, Patterson and Banker pages 35,36,85,86

```
C
C           PRELIMINARY TREATMENT
C           PROCESS IDENTIFICATION NUMBER   1
C
      SUBROUTINE PREL
C
C
C           COMMON INITIAL STATEMENTS
C
      INTEGER OS1,OS2
      COMMON SMATX(20,30),TMATX(20,30),DMATX(20,20),OMATX(20,20),IP(20),
     1INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),ACOST(20,5)
     2,TCOST(20,5),DHR,PCT,WPI,CLAND,DLAND,FLOW(25),POW(25),TKWHD(25)
C
C
C           ASSIGNMENT OF DESIGN VALUES TO PROCESS PARAMETERS
C
      IPREL=DMATX(1,N)
C
C
C           EFFLUENT STREAM CALCULATIONS
C
      DO 10 I=2,20
   10 SMATX(I,OS1)=SMATX(I,IS1)
C
C
C           CALC. OF CAPITAL COSTS BASED ON DESIGN PLUS EXCESS
C           CAPACITY
C
      X=ALOG(SMATX(2,IS1)*DMATX(16,N))
      IF (IPREL) 30,20,30
C
C
C                 CALC. OF CAPITAL COSTS FOR PRELIMINARY FACILITY
C                 CONSISTING OF GRIT REMOVAL AND FLOW MEASUREMENT
C
   20 CCOST(N,1)=EXP(2.566509+.619151*X)*1000.
      GO TO 40
C
C
C                 CALC. OF CAPITAL COSTS FOR PRELIMINARY FACILITY
C                 CONSISTING OF GRIT REMOVAL AND FLOW MEASUREMENT AND
C                 SCREENING
C
   30 CCOST(N,1)=EXP(3.259716+.619151*X)*1000.
C
C
C           CALC. OF OPERATING COSTS BASED ON DESIGN CAPACITY ALONE,
C           DOES NOT INCLUDE EXCESS CAPACITY
C
   40 X=ALOG(SMATX(2,IS1))
C
C
C                 CALC.OF OPERATING MANHOURS, MAINTENANCE MANHOURS
C                 AND MATERIALS AND SUPPLIES
C
      OHRS=EXP(6.398716+.230956*X+.164959*X**2.-.014601*X**3.)
      XMHRS=EXP(5.846098+.206513*X+.068842*X**2.+.023824*X**3.-.004410*X
     1**4.)                                                             PRE05900
      TMSU=EXP(7.235657+.399935*X-.224979*X**2.+.110099*X**3.-.011026*X*PRE06000
     1*4.)                                                              PRE06100
C                                                                       PRE06200
C                                                                       PRE06300
C                 OPERATING COST EQUATION                               PRE06400
C                                                                       PRE06500
      COSTO(N,1)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*P1)/SMATX(2,1)/3650.   PRE06600
C                                                                       PRE06700
C                                                                       PRE06800
C              PROCESS ENERGY INDICES                                   PRE06900
C                                                                       PRE07000
      FLOW(N)=SMATX(2,IS1)                                              PRE07100
      POW(N)=1.                                                         PRE07200
      RETURN                                                            PRE07300
      END                                                               PRE07400
```

SECTION 3

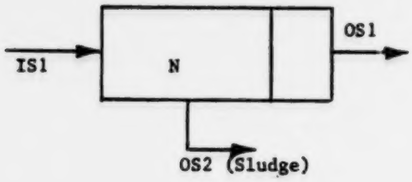
PRIMARY SEDIMENTATION, PRSET

Subroutine Identification Number 2

Primary Sedimentation, PRSET

Rev. Date 8/1/77

1. Process symbol.



IS1: Liquid input stream

OS1: Liquid output stream

OS2: Sludge output stream

N: User assigned number to the process

2. Input parameters and nominal values.

DMATX(1,N) = FRPS	Fraction of solids entering the primary settler which is removed from the main stream and sent on to the sludge handling process, fraction. [.5]
DMATX(2,N) = URPS	Ratio of solids concentration in OS2 from the primary settler to the solids concentration in IS1 to the primary settler. [400.]
DMATX(3,N) = HPWK	Hours per week that the primary sludge pumps are operated, hr/wk. [14.]
DMATX(15,N) = ECF	Excess capacity factor for primary sludge pumps. [1.]
DMATX(16,N) = ECF	Excess capacity factor for primary settler basin. [1.2]

3. Output Parameters which are printed on computer output sheets.

FRPS = DMATX(1,N)	
URPS = DMATX(2,N)	
HPWK = DMATX(3,N)	
GPS = OMATX(1,N)	Overflow rate for the primary settler, [gpd/sq/ft].
APS = OMATX(2,N)	Surface area of the primary settler, [sq ft/1000].
PGPM = OMATX(3,N)	Firm pumping capacity of the primary sludge pumps, [gpm].
CCOST	Capital cost, [dollars] .
COSTO	Operating and maintenance costs, [cents/1000 gal].
ACOST	Amortization cost, [cents/1000 gal].
TCOST	Total treatment cost, [cents/1000 gal].
ECF	Excess capacity factor.

4. Theory and function - FORTRAN statement followed by equivalent algebraic equation.

HPWK = DMATX(3,N) PRS01800

HPWK = DMATX(3,N) [hr/wk]

SMATX(2,OS2) = DMATX(1,N)*SMATX(2,IS1)/DMATX(2,N) PRS02400

$$Q_{OS2} = \frac{FRPS*Q_{IS1}}{URPS} \quad [MGD]$$

SMATX(2,OS1) = SMATX(2,IS1)-SMATX(2,OS2) PRS02500

$$Q_{OS1} = Q_{IS1} - Q_{OS2} \quad [MGD]$$

TEMP1 = (1.-DMATX(1,N))*SMATX(2,IS1)/SMATX(2,OS1) PRS02600

$$TEMP1 = \frac{(1.0-FRPS)*Q_{IS1}}{Q_{OS1}} \quad [\text{no units}]$$

TEMP2 = DMATX(1,N)*SMATX(2,IS1)/SMATX(2,OS2) PRS02700

$$TEMP2 = \frac{FRPS*Q_{IS1}}{Q_{OS2}} \quad [\text{no units}]$$

SMATX(I,OS1) = TEMP1*SMATX(I,IS1) PRS03300

SMATX(I,OS1) = TEMP1*SMATX(I,IS1) [mg/l]

where I = 3,10 i.e. SOC,SNBC,SON,SOP,SFM,SBOD,VSS,TSS

SMATX(I,OS2) = TEMP2*SMATX(I,IS1) PRS03400

SMATX(I,OS2) = TEMP2*SMATX(I,IS1) [mg/l]

where I = 3,10

SMATX(I,OS2) = SMATX(I,IS1) PRS03600

SMATX(I,OS2) = SMATX(I,IS1) [mg/l]

where I = 11,20 i.e. DOC,DNBC,DN,DP,DFM,ALK,DBOD,NH3,NO3

SMATX(I,OS1) = SMATX(I,OS2) PRS03700

SMATX(I,OS1) = SMATX(I,OS2) [mg/l]

where I = 11,20

```
GPS = -2780.*ALOG(DMATX(1,N))-551.7                                   PRS04300
```

$$GPS = -(2780*\ln FRPS)-551.7 \quad [gpd/ft^2]$$

```
APS = SMATX(2,IS1) *1000./GPS*DMATX(16,N)                             PRS04400
```

$$APS = \frac{Q_{IS1}*1000ECF}{GPS} \quad [1000ft^2]$$

```
PGPM = SMATX(2,OS2)*116666.7/HPWK*DMATX(15,N)                         PRS04200
```

$$PGPM = \frac{Q_{OS2}*116666.7*ECF}{HPWK} \quad [gpm]$$

Reference: Smith, 1969

Smith and Eilers, 1975

Patterson and Banker, 1971

5. Cost Functions.

a. Settler

(1) Capital cost for the settler

Function of APS

```
X = ALOG(APS)                                                         PRS05000
```

$$X = \ln APS$$

```
CCOST(N,1) = EXP(3.716354+.389861*X+.084560*X**2.-.004718*X**3.)*1000. PRS05100
```

$$CCOST = 1000e^{3.716354+0.389861X+0.084560X^2-0.004718X^3} \quad [dollars]$$

(2) Operating manhours, maintenance manhours and materials/supplies costs

Function of APS/ECF

```
X = ALOG(APS/DMATX(16,N))                                             PRS05900
```

$$X = \ln \frac{APS}{ECF}$$

(a) Operating manhours

```
OHRS = EXP(5.846565+.254813*X+.113703*X**2.-.010942*X**3.)   PRS06500
```

$$OHRS = e^{5.846565+0.254813X+0.113703X^2-0.010942X^3} \quad [hrs/yr]$$

(b) Maintenance manhours

```
XMHRS = EXP(5.273419+.228329*X+.122646*X**2.-.011672*X**3.)    PRS06600
```

$$XMHRS = e^{5.273419+0.228329X+0.122646X^2-0.011672X^3} \quad [hrs/yr]$$

(c) Total materials and supplies

```
TMSU = EXP(5.669881+.750799*X)                                 PRS06700
```

$$TMSU = e^{5.669881+0.750799X} \quad [\$/yr]$$

(3) Total operating and maintenance costs

```
COSTO(N,1) = ((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650. PRS07200
```

$$COSTO = \frac{[(OHRS+XMHRS)DHR(1+PCT)]+(TMSU*WPI)}{Q_{Plant\ Inf.}*3650} \quad [cents/1000\ gal]$$

b. Sludge pumps

(1) Capital cost for sludge pumps

Function of PGPM

```
X = ALOG(PGPM)                                                 PRS07800
```

$$X = \ln(PGPM)$$

```
CCOST(N,2) = EXP(2.237330+.207628*X+.026479*X**2.)*1000.      PRS07900
```

$$CCOST = 1000e^{2.237330+0.207628X+0.026479X^2} \quad [dollars]$$

(2) Operating manhours, maintenance manhours and materials/supplies costs

Function of PGPM/ECF

```
X = ALOG(PGPM/DMATX(15,N))                                     PRS08500
```

$$X = \ln\frac{PGPM}{ECF}$$

(a) Operating manhours

```
OHRS = EXP(4.945155+.419391*X)                                 PRS09100
```

$$OHRS = e^{4.945155+0.419391X} \quad [hrs/yr]$$

(b) Maintenance manhours

```
XMHRS = EXP(3.993365+.444966*X)                                PRS09200
```

$$XMHRS = e^{3.993365+0.444966X} \quad [hrs/yr]$$

(c) Total materials and supplies

```
TMSU = EXP(4.433129+.642272*X)                                PRS09300
```

$$\mathrm{TMSU} = e^{4.433129+0.642272X} \quad [\$/\mathrm{yr}]$$

(3) Total operating and maintenance costs

```
COSTO(N,2) = ((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650. PRS09800
```

$$\mathrm{COSTO} = \frac{[(\mathrm{OHRS}+\mathrm{XMHRS})\mathrm{DHR}(1+\mathrm{PCT})](\mathrm{TMSU}*\mathrm{WPI})}{Q_{\mathrm{Plant\ Inf.}}*3650} \quad [\mathrm{cents}/1000\mathrm{gal}]$$

```
C
C           PRIMARY SEDIMENTATION
C           PROCESS IDENTIFICATION NUMBER   2
C
      SUBROUTINE PRSET
C
C
C           COMMON INITIAL STATEMENTS
C
      INTEGER OS1,OS2
      COMMON SMATX(20,30),TMATX(20,30),DMATX(20,20),OMATX(20,20),IP(20),
     1INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),ACOST(20,5)
     2,TCOST(20,5),DHR,PCT,WPI,CLAND,DLAND,FLOW(25),POW(25),TKWHD(25)
C
C
C           ASSIGNMENT OF DESIGN VALUES TO PROCESS PARAMETERS
C
      HPWK=DMATX(3,N)
C
C
C           PROCESS RELATIONSHIPS REQD. TO CALC. EFFLUENT STREAM
C           CHARACTERISTICS
C
      SMATX(2,OS2)=DMATX(1,N)*SMATX(2,IS1)/DMATX(2,N)
      SMATX(2,OS1)=SMATX(2,IS1)-SMATX(2,OS2)
      TEMP1=(1.-DMATX(1,N))*SMATX(2,IS1)/SMATX(2,OS1)
      TEMP2=DMATX(1,N)*SMATX(2,IS1)/SMATX(2,OS2)
C
C
C           EFFLUENT STREAM CALCULATIONS
C
      DO 10 I=3,10
      SMATX(I,OS1)=TEMP1*SMATX(I,IS1)
   10 SMATX(I,OS2)=TEMP2*SMATX(I,IS1)
      DO 20 I=11,20
      SMATX(I,OS2)=SMATX(I,IS1)
   20 SMATX(I,OS1)=SMATX(I,OS2)
C
C
C           CALC. OF OUTPUT SIZES AND QUANTITIES
C
      PGPM=SMATX(2,OS2)*116666.7/HPWK*DMATX(15,N)
      GPS=-2780.*ALOG(DMATX(1,N))-551.7
      APS=SMATX(2,IS1)*1000./GPS*DMATX(16,N)
C
C
C           CALC. OF CAPITAL COSTS FOR PRIMARY SETTLER BASIN BASED
C           ON DESIGN PLUS EXCESS CAPACITY
C
      X=ALOG(APS)
      CCOST(N,1)=EXP(3.716354+.389861*X+.084560*X**2.-.004718*X**3.)*100
     10.
C
C
C           CALC. OF OPERATING COSTS FOR PRIMARY SETTLER BASIN BASED
C           ON DESIGN CAPACITY ALONE, DOES NOT INCLUDE EXCESS
C           CAPACITY
C
```

```
      X=ALOG(APS/DMATX(16,N))                                           PRS05900
C                                                                       PRS06000
C                                                                       PRS06100
C                 CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS     PRS06200
C                 AND MATERIALS AND SUPPLIES                            PRS06300
C                                                                       PRS06400
      OHRS=EXP(5.846565+.254813*X+.113703*X**2.-.010942*X**3.)          PRS06500
      XMHRS=EXP(5.273419+.228329*X+.122646*X**2.-.011672*X**3.)         PRS06600
      TMSU=EXP(5.669881+.750799*X)                                      PRS06700
C                                                                       PRS06800
C                                                                       PRS06900
C                 OPERATING COST EQUATION                               PRS07000
C                                                                       PRS07100
      COSTO(N,1)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*EPI)/SMATX(2,1)/3650.  PRS07200
C                                                                       PRS07300
C                                                                       PRS07400
C           CALC. OF CAPITAL COSTS FOR SLUDGE PUMPS BASED ON DESIGN     PRS07500
C           PLUS EXCESS CAPACITY                                        PRS07600
C                                                                       PRS07700
      X=ALOG(PGPM)                                                      PRS07800
      CCOST(N,2)=EXP(2.237330+.207628*X+.026479*X**2.)*1000.            PRS07900
C                                                                       PRS08000
C                                                                       PRS08100
C           CALC. OF OPERATING COSTS FOR SLUDGE PUMPS BASED ON          PRS08200
C           DESIGN CAPACITY ALONE, DOES NOT INCLUDE EXCESS CAPACITY     PRS08300
C                                                                       PRS08400
      X=ALOG(PGPM/DMATX(15,N))                                          PRS08500
C                                                                       PRS08600
C                                                                       PRS08700
C                 CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS     PRS08800
C                 AND MATERIALS AND SUPPLIES                            PRS08900
C                                                                       PRS09000
      OHRS=EXP(4.945155+.419391*X)                                      PRS09100
      XMHRS=EXP(3.993365+.444966*X)                                     PRS09200
      TMSU=EXP(4.433129+.642272*X)                                      PRS09300
C                                                                       PRS09400
C                                                                       PRS09500
C                 OPERATING COST EQUATION                               PRS09600
C                                                                       PRS09700
      COSTO(N,2)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*EPI)/SMATX(2,1)/3650.  PRS09800
C                                                                       PRS09900
C                                                                       PRS10000
C           ASSIGNMENT OF VALUES TO OMATX                               PRS10100
C                                                                       PRS10200
      OMATX(1,N)=GPS                                                    PRS10300
      OMATX(2,N)=APS                                                    PRS10400
      OMATX(3,N)=PGPM                                                   PRS10500
C                                                                       PRS10600
C                                                                       PRS10700
C           PROCESS ENERGY INDICES                                      PRS10800
C                                                                       PRS10900
      FLOW(N)=SMATX(2,IS1)                                              PRS11000
      POW(N)=2.                                                         PRS11100
      RETURN                                                            PRS11200
      END                                                               PRS11300
```

SECTION 4

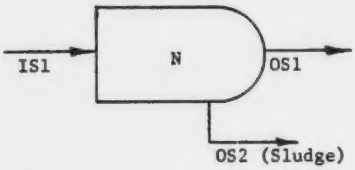
ACTIVATED SLUDGE - FINAL SETTLER, AERFS

Subroutine Identification Number 3

Rev. Date 8/1/77

Activated Sludge - Final Settler, AERFS

1. Process Symbol.



IS1: Liquid input stream
OS1: Liquid output stream
OS2: Sludge output stream
N: User assigned number to the process

2. Input parameters and nominal values.

DMATX(1,N) = BOD	Demand concentration of 5-day BOD in the final effluent from the aeration process, mg/1.[13.]
DMATX(2,N) = MLSS	Total concentration of suspended solids in the aerator, mg/1 mass.[2000.]
DMATX(3,N) = DEGC	Water temperature, degrees Centigrade.[20.]
DMATX(4,N) = CAER20	Rate constant used for sizing the aerator when the water temperature is 20° C. 1/(hr gm/L)[1.]
DMATX(5,N) = DO	Concentration of dissolved oxygen in the aerator, mg/1 oxygen.[1.]
DMATX(6,N) = AEFF20	Efficiency of the air diffusers in the aerator at zero dissolved oxygen and 20°C.[.05]
DMATX(7,N) = URSS	Ratio of solids concentration in OS2 (underflow stream) from the final settler to the total solids concentration in the aerator.[3.]
DMATX(8,N) = GSS	Design overflow rate for the final settler, gpd/sq ft.[700.]
DMATX(9,N) = HEAD	Pumping head for the sludge return pumps, ft.[30.]
DMATX(10,N) = ALMD	Dose of aluminum added to the aerator, mg/1 aluminum.[0.]
DMATX(13,N) = ECF	Excess capacity factor for the final settler.[1.2]
DMATX(14,N) = ECF	Excess capacity factor for the sludge return pumps.[1.]
DMATX(15,N) = ECF	Excess capacity factor for the air blowers.[1.]
DMATX(16,N) = ECF	Excess capacity factor for the aeration tanks.[1.2]

3. Output parameters which are printed on computer output sheets.

BOD = DMATX(1,N)	
MLSS = DMATX(2,N)	
DEGC = DMATX(3,N)	
CAER20 = DMATX(4,N)	
DO = DMATX(5,N)	
AEFF20 = DMATX(6,N)	
URSS = DMATX(7,N)	
GSS = DMATX(8,N)	
HEAD = DMATX(9,N)	
ALMD = DMATX(10,N)	
BOD2 = OMATX(1,N)	Influent concentration of 5-day BOD to the aeration process, mg/l.
DOSAT = OMATX(2,N)	Saturation value for dissolved oxygen in the aerator at one-half the water depth, mg/l oxygen.
XRSS = OMATX(3,N)	Ratio of solids concentration of OS1 from the final settler to the total solids concentration in the aerator.
AFS = OMATX(4,N)	Surface area of the final settler, sq ft/1000.

CAER = OMATX(5,N)	Rate constant for sizing the aerator corrected for water temperature, (1/(hr gm/L)).
CEDR = OMATX(6,N)	Rate at which active solids are destroyed by natural causes in the aerator, fraction of mass per day.
VAER = OMATX(7,N)	Volume of the aerator, million gallons.
VNIT = OMATX(8,N)	Volume of the aerator required to achieve nitrification, million gallons.
MLASS = OMATX(9,N)	XMLAS, concentration of active solids held in the aerator, mg/l mass.
MLBSS = OMATX(10,N)	XMLBS, concentration of unmetabolized biodegradable solids held in the aerator, mg/l mass.
MLNBSS = OMATX(11,N)	XMLNB, concentration of non-biodegradable organic solids held in the aerator, mg/l mass.
MLDSS = OMATX(12,N)	XMLDS, concentration of non-biodegradable solids in the aerator caused by the destruction of active solids through natural causes, mg/l mass.
MLISS = OMATX(13,N)	XMLIS, concentration of inert inorganic solids in the aerator caused by inorganic solids in the influent stream, mg/l mass.
FOOD = OMATX(14,N)	Synthesis rate of 5-day BOD to active solids in the aerator each day, mg/l oxygen.
RTURN = OMATX(15,N)	Sludge return ratio for the aerator.
CNIT = OMATX(16,N)	Rate constant for nitrification. (1/day)
ARCFD = OMATX(17,N)	Diffused air requirement for the aerator, scf/day.

BSIZE = OMATX(18,N)	**Required size of the blower for supplying to the aerator, cfm.**
CFPGL = OMATX(19,N)	**Diffused air requirements for the aerator, scf/gallon of sewage entering the system.**
QR = OMATX(20,N)	**Volume of the return sludge stream, mgd.**
CCOST	**Capital cost,[dollars].**
COSTO	**Operating and maintenance costs,[cents/1000gal].**
ACOST	**Amortization cost,[cents/1000gal].**
TCOST	**Total treatment cost,[cents/1000gal].**
ECF	**Excess capacity factor.**

4. Theory and functions - FORTRAN statement followed by equivalent algebraic equation.

BOD2 = SMATX(8,IS1)+SMATX(17,IS1) AEF02000

$$BOD2 = SBOD_{IS1}+DBOD_{IS1} \qquad [mg/l]$$

DBOD2 = SMATX(17,IS1) AEF02100

$$DBOD2 = DBOD_{IS1} \qquad [mg/l]$$

CEDR = .18*1.047**(DMATX(3,N)-28.) AEF02200

$$CEDR = 0.18(1.047)^{DEGC-28} \qquad \left[\frac{1}{Day}\right]$$

CAER = DMATX(4,N)*1.047**(DMATX(3,N)-20.) AEF02300

$$CAER = CAER20[1.047]^{DEGC-20} \qquad \left[\frac{1}{hr\ \frac{gm}{l}}\right]$$

SA = DMATX(2,N)/1000. AEF02400

$$SA = \frac{MLSS}{1000} \qquad [gm/l]$$

TA = (BOD2-DMATX(1,N))/(DMATX(1,N)*CAER*SA*24.) AEF02500

$$TA = \frac{BOD2-BOD}{BOD*CAER*24*SA} \qquad [days]$$

VAER = SMATX(2,IS1)*TA AEF02600

$$VAER = Q_{IS1}*TA \qquad [MG]$$

```
XRSS = 556.1*DMATX(8,N)**.4942/DMATX(2,N)**1.8165/(TA*24.)**.4386     AEF02700
```

$$XRSS = \frac{556.1*[GSS]^{0.4942}}{[MLSS]^{1.8165}*[24TA]^{0.4386}} \qquad \text{[no units]}$$

```
ALD = DMATX(10,N)*.87*SMATX(14,IS1)                                   AEF02800
```

$$ALD = 0.87ALMD*DP_{IS1} \qquad \text{[mg/l]}$$

```
PALS = 1.305*SMATX(14,IS1)+3.*ALD                                     AEF03000
```

$$PALS = 1.305DP_{IS1}+3ALD \qquad \text{[mg/l]}$$

```
ASMAX = DMATX(1,N)/XRSS/.685                                          AEF03300
```

$$ASMAX = \frac{BOD}{0.685XRSS} \qquad \text{[mg/l]}$$

```
XMLAS = (ASMAX+ASMIN)/2.                                              AEF03800
```

$$XMLAS = \frac{ASMAX+ASMIN}{2} \qquad \text{[mg/l]}$$

```
FOOD = SMATX(8,IS1)+DBOD2                                             AEF03900
```

$$FOOD = SBOD_{IS1}+DBOD2 \qquad \text{[mg/l]}$$

```
FMAX = FOOD                                                           AEF04000
```

$$FMAX = SBOD_{IS1}+DBOD2 \qquad \text{[mg/l]}$$

```
ERROR = FMAX-FMIN                                                     AEF04300
```

$$ERROR = FMAX-FMIN \qquad \text{[mg/l]}$$

```
FOOD = (FMAX+FMIN)/2.                                                 AEF04500
```

$$FOOD = \frac{FMAX+FMIN}{2} \qquad \text{[mg/l]}$$

```
DBOD4 = SMATX(17,IS1)-FOOD                                            AEF04700
```

$$DBOD4 = DBOD_{IS1}-FOOD \qquad \text{[mg/l]}$$

```
SBOD4 = SMATX(8,IS1)                                                    AEF04800
```

$$SBOD4 = SBOD_{IS1}$$ [mg/l]

```
SBOD4 = (SMATX(8,IS1)+SMATX(17,IS1)-FOOD)*.7                            AEF05000
```

$$SBOD4 = 0.7(SBOD_{IS1}+DBOD_{IS1}-FOOD)$$ [mg/l]

```
DBOD4 = .233*SBOD4                                                      AEF05100
```

$$DBOD4 = 0.233*0.7(SBOD_{IS1}+DBOD_{IS1}-FOOD)$$ [mg/l]

```
TEMP1 = .50*FOOD/XMLAS-XRSS                                             AEF05200
```

$$TEMP1 = \frac{0.50FOOD}{XMLAS} -XRSS$$ [no units]

```
SMATX(2,OS2) = (SMATX(2,IS1)*TEMP1-CEDR*VAER)/(DMATX(7,N)-XRSS)         AEF05300
```

$$Q_{OS2} = \frac{(Q_{IS1}*TEMP1)-(CEDR*VAER)}{URSS-XRSS}$$ [MGD]

```
SMATX(2,OS1) = SMATX(2,IS1)-SMATX(2,OS2)                                AEF05400
```

$$Q_{OS1} = Q_{IS1}-Q_{OS2}$$ [MGD]

```
TEMP2 = XRSS*SMATX(2,OS1)+DMATX(7,N)*SMATX(2,OS2)                       AEF05700
```

$$TEMP2 = (XRSS*Q_{OS1})+(URSS*Q_{OS2})$$ [MGD]

```
XMLBS = SMATX(2,IS1)*SBOD4/TEMP2/.8                                     AEF05800
```

$$XMLBS = \frac{Q_{IS1}*SBOD4}{0.8TEMP2}$$ [mg/l]

```
SMATX(8,OS1) = (XMLAS*.685+XMLBS*.8)*XRSS                               AEF05900
```

$$SBOD_{OS1} = (0.685XMLAS+0.8XMLBS)XRSS$$ [mg/l]

```
SMATX(17,OS1) = DBOD4                                                   AEF06000
```

$$DBOD_{OS1} = DBOD4$$ [mg/l]

`TBOD5 = SMATX(8,OS1)+SMATX(17,OS1)` AEF06100

$$TBOD5 = SBOD_{OS1}+DBOD_{OS1}$$ [mg/l]

`TBOD5 = XMLAS*XRSS*.685` AEF06300

$$TBOD5 = 0.685XMLAS*XRSS$$ [mg/l]

`FMIN = (CEDR*VAER/SMATX(2,IS1)+XRSS)*XMLAS/.50` AEF06600

$$FMIN = \left[\frac{CEDR*VAER}{Q_{IS1}}+XRSS\right]*\frac{XMLAS}{0.50}$$ [mg/l]

`FOOD = FMIN` AEF06700

$$FOOD = \frac{XMLAS}{0.50}\left[\frac{CEDR*VAER}{Q_{IS1}}+XRSS\right]$$ [mg/l]

`FMAX = FOOD` AEF07300

$$FMAX = FOOD$$ [mg/l]

`FMIN = FOOD` AEF08000

$$FMIN = FOOD$$ [mg/l]

`XMLNB = SMATX(4,IS1)*SMATX(2,IS1)*2.13/TEMP2` AEF08200

$$XMLNB = \frac{SNBC_{IS1}*Q_{IS1}*2.13}{TEMP2}$$ [mg/l]

`XMLIS = SMATX(2,IS1)*(SMATX(7,IS1)+PALS)/TEMP2` AEF08300

$$XMLIS = \frac{Q_{IS1}(SFM_{IS1}+PALS)}{TEMP2}$$ [mg/l]

`XMLDS = .12*SMATX(2,IS1)*FOOD/TEMP2-.185*XMLAS` AEF08400

$$XMLDS = \frac{0.12Q_{IS1}*FOOD}{TEMP2} - 0.185XMLAS$$ [mg/l]

`TEMP3 = XMLAS+XMLBS+XMLNB+XMLDS+XMLIS` AEF08500

$$TEMP3 = XMLAS+XMLBS+XMLNB+XMLDS+XMLIS$$ [mg/l]

```
TEMP4 = TEMP3-DMATX(2,N)                                          AEF08600
```

$$\mathrm{TEMP4} = \mathrm{TEMP3} - \mathrm{MLSS} \qquad [\mathrm{mg/l}]$$

```
ASMIN = XMLAS                                                     AEF09500
```

$$\mathrm{ASMIN} = \mathrm{XMLAS} \qquad [\mathrm{mg/l}]$$

```
ASMAX = XMLAS                                                     AEF09700
```

$$\mathrm{ASMAX} = \mathrm{XMLAS} \qquad [\mathrm{mg/l}]$$

```
SMATX(3,OS1) = (XMLDS+XMLAS)*XRSS/2.46+(XMLBS+XMLNB)*XRSS/2.33    AEF10300
```

$$\mathrm{SOC}_{\mathrm{OS1}} = \frac{(\mathrm{XMLDS}+\mathrm{XMLAS})\mathrm{XRSS}}{2.46} + \frac{(\mathrm{XMLBS}+\mathrm{XMLNB})\mathrm{XRSS}}{2.33} \qquad [\mathrm{mg/l}]$$

```
SMATX(4,OS1) = XMLNB*XRSS/2.33+(XMLDS+.185*XMLAS)*XRSS/2.46       AEF10400
```

$$\mathrm{SNBC}_{\mathrm{OS1}} = \frac{\mathrm{XMLNB*XRSS}}{2.33} + \frac{(\mathrm{XMLDS}+0.185\mathrm{XMLAS})\mathrm{XRSS}}{2.46} \qquad [\mathrm{mg/l}]$$

```
TEMP5 = XRSS*XMLAS/2.46                                           AEF10500
```

$$\mathrm{TEMP5} = \frac{\mathrm{XRSS*XMLAS}}{2.46} \qquad [\mathrm{mg/l}]$$

```
SMATX(5,OS1) = .234*TEMP5+(SMATX(3,OS1)-TEMP5)/10.                AEF10600
```

$$\mathrm{SON}_{\mathrm{OS1}} = 0.234\mathrm{TEMP5} + \frac{\mathrm{SOC}_{\mathrm{OS1}} - \mathrm{TEMP5}}{10} \qquad [\mathrm{mg/l}]$$

```
SMATX(6,OS1) = SMATX(3,OS1)*.01                                   AEF10700
```

$$\mathrm{SOP}_{\mathrm{OS1}} = 0.01\mathrm{SOC}_{\mathrm{OS1}} \qquad [\mathrm{mg/l}]$$

```
SMATX(7,OS1) = XMLIS*XRSS                                         AEF10800
```

$$\mathrm{SFM}_{\mathrm{OS1}} = \mathrm{XMLIS*XRSS} \qquad [\mathrm{mg/l}]$$

```
SMATX(9,OS1) = SMATX(3,OS1)*2.38                              AEF10900
```

$$VSS_{OS1} = 2.38SOC_{OS1} \qquad \text{[mg/l]}$$

```
SMATX(10,OS1) = SMATX(7,OS1)+SMATX(9,OS1)                     AEF11000
```

$$TSS_{OS1} = SFM_{OS1}+VSS_{OS1} \qquad \text{[mg/l]}$$

```
SMATX(I,OS2) = SMATX(I,OS1)*DMATX(7,N)/XRSS                   AEF11200
```

$$SMATX(I,OS2) = \frac{SMATX(I,OS1)*URSS}{XRSS} \qquad \text{[mg/l]}$$

where I = 3,10 i.e. SOC,SNBC,SON,SOP,SFM,SBOD,VSS,TSS

```
SMATX(11,OS1) = SMATX(12,IS1)+DBOD4/1.87                      AEF11300
```

$$DOC_{OS1} = DNBC+ \frac{DBOD4}{1.87} \qquad \text{[mg/l]}$$

```
SMATX(12,OS1) = SMATX(12,IS1)                                 AEF11400
```

$$DNBC_{OS1} = DNBC_{IS1} \qquad \text{[mg/l]}$$

```
SMATX(13,OS1) = (SMATX(2,IS1)*(SMATX(5,IS1)+SMATX(13,IS1))-(SMATX(5,OS1)*SMATX(2,OS1)
                +SMATX(5,OS2)*SMATX(2,OS2)))/(SMATX(2,OS1)+SMATX(2,OS2))
```

$$DN_{OS1} = \frac{Q_{IS1}(SON_{IS1}+DN_{IS1})-(SON_{IS1}*Q_{OS1}+SON_{OS2}*Q_{OS2})}{Q_{OS1}+Q_{OS2}} \qquad \begin{matrix}\text{AEF11500}\\ \text{[mg/l]}\end{matrix}$$

```
SMATX(14,OS1) = (SMATX(2,IS1)*(SMATX(6,IS1)+SMATX(14,IS1))-(SMATX(6,OS1)*SMATX(2,OS1)
                +SMATX(6,OS2)*SMATX(2,OS2)))/(SMATX(2,OS1)+SMATX(2,OS2))
```

$$DP_{OS1} = \frac{Q_{IS1}(SOP_{IS1}+DP_{IS1})-(SOP_{OS1}*Q_{OS1}+SOP_{OS2}*Q_{OS2})}{Q_{OS1}+Q_{OS2}} \qquad \begin{matrix}\text{AEF11800}\\ \text{[mg/l]}\end{matrix}$$

```
SMATX(15,OS1) = SMATX(15,IS1)                                 AEF12100
```

$$DFM_{OS1} = DFM_{IS1} \qquad \text{[mg/l]}$$

```
SMATX(I,OS2) = SMATX(I,OS1)                                     AEF12300
```

$$SMATX(I,OS2) = SMATX(I,OS1)$$ [mg/l]

where I = 11, 15 i.e. DOC,DNBC,DN,DP,DFM

```
QR = (SMATX(2,IS1)*(1.-.50*FOOD/XMLAS)+CEDR*VAER)/(SMATX(7,N)-1.) AEF12400
```

$$QR = \frac{Q_{IS1}\left[1-\frac{0.50FOOD}{XMLAS}\right]+(CEDR*VAER)}{URSS-1}$$ [mg/l]

```
RTURN = QR/SMATX(2,IS1)                                         AEF12500
```

$$RTURN = \frac{QR}{Q_{IS1}}$$ [no units]

```
X4X3 = (1.+RTURN)/RTURN/SMATX(7,N)                              AEF12600
```

$$X4X3 = \frac{1+RTURN}{RTURN*URSS}$$ [no units]

```
DN3 = SMATX(13,IS1)/(1.+RTURN)                                  AEF12700
```

$$DN3 = \frac{DN_{IS1}}{1+RTURN}$$ [mg/l]

```
X3Y = DN3*.99/(X4X3-1.)                                         AEF12800
```

$$X3Y = \frac{0.99DN3}{X4X3-1}$$ [mg/l]

```
CNIT = .18*EXP(.116*(DMATX(3,N)-15.))                           AEF12900
```

$$CNIT = 0.18e^{0.116(DEGC-15)}$$ [1/days]

```
TTAN = (1.+RTURN)*ALOG(X4X3)+4.605/(DN3+X3Y))/CNIT              AEF13300
```

$$TTAN = (1+RTURN)*\ln X4X3+\frac{4.605}{(DN3+X3Y)CNIT}$$ [days]

VNIT = SMATX(2,IS1)*TTAN AEF13400

$VNIT = Q_{IS1}*TTAN$ [MG]

SMATX(16,OS1) = SMATX(16,IS1)+3.57*(SMATX(13,OS1)-SMATX(13,IS1)) AEF13600

$ALK_{OS1} = ALK_{IS1}+3.57(DN_{OS1}-DN_{IS1})$ [mg/l]

SMATX(16,OS1) = SMATX(16,IS1) AEF13800

$ALK_{OS1} = ALK_{IS1}$ [mg/l]

SMATX(16,OS2) = SMATX(16,OS1) AEF13900

$ALK_{OS2} = ALK_{OS1}$ [mg/l]

SMATX(17,OS2) = SMATX(17,OS1) AEF14000

$DBOD_{OS2} = DBOD_{OS1}$ [mg/l]

SMATX(18,OS1) = SMATX(18,IS1) AEF14100

$NH3_{OS1} = NH3_{IS1}$ [mg/l]

SMATX(18,OS2) = SMATX(18,IS1) AEF14200

$NH3_{OS2} = NH3_{IS1}$ [mg/l]

SMATX(19,OS1) = SMATX(19,IS1) AEF14300

$NO3_{OS1} = NO3_{IS1}$ [mg/l]

SMATX(19,OS2) = SMATX(19,IS1) AEF14400

$NO3_{OS2} = NO3_{IS1}$ [mg/l]

`SMATX(20,OS1) = SMATX(20,IS1)` AEF14500

For future parameter [mg/1]

`SMATX(20,OS2) = SMATX(20,IS1)` AEF14600

For future parameter [mg/1]

`DOSAT = (14.16-.3943*DMATX(3,N)+.007714*DMATX(3,N)**2.-.0000646*DMATX(3,N)**3)*1.221`

$\mathrm{DOSAT} = 1.221(14.16-0.3943\mathrm{DEGC}+0.007714\mathrm{DEGC}^2-0.0000646\mathrm{DEGC}^3)$ [mg/1] AEF15100

`AEFF = DMATX(6,N)*(DOSAT-DMATX(5,N))*1.02**(DMATX(3,N)-20.)/DOSAT` AEF15300

$\mathrm{AEFF} = \frac{\mathrm{AEFF20}*(\mathrm{DOSAT}-\mathrm{DO})*[1.02]^{\mathrm{DEGC}-20}}{\mathrm{DOSAT}}$ [no units]

`WFOOD = SMATX(2,IS1)*FOOD*8.33` AEF15400

$\mathrm{WFOOD} = 8.33Q_{\mathrm{IS1}}*\mathrm{FOOD}$ [lb/day]

`WAS = XMLAS*VAER*8.33` AEF15500

$\mathrm{WAS} = 8.33\mathrm{XMLAS}*\mathrm{VAER}$ [lb/day]

`ARCFD = (.577*WFOOD+1.16*CEDR*WAS)/AEFF/.232/.075` AEF15600

$\mathrm{ARCFD} = \frac{0.577\mathrm{WFOOD}+(1.16\,\mathrm{DECR}*\mathrm{WAS})}{0.232\mathrm{AEFF}*0.075}$ $[\frac{\mathrm{ft}^3}{\mathrm{day}}]$

`WDN = (SMATX(2,OS1)*SMATX(13,OS1)+SMATX(2,OS2)*SMATX(13,OS2))*8.33` AEF15700

$\mathrm{WDN} = 8.33((Q_{\mathrm{OS1}}*\mathrm{DN}_{\mathrm{OS1}})+(Q_{\mathrm{OS2}}*\mathrm{DN}_{\mathrm{OS2}}))$ [lb/day]

`ARCFD = ARCFD+4.6*WDN/AEFF/.232/.075` AEF15900

$\mathrm{ARCFD} = \mathrm{ARCFD}+\frac{4.6\mathrm{WDN}}{0.232\mathrm{AEFF}*0.75}$ $[\mathrm{ft}^3/\mathrm{day}]$

BSIZE = DMATX(15,N)*ARCFD/1440. AEF16000

$$BSIZE = \frac{ECF_b*ARCFD}{1440} \quad [cfm]$$

CFPGL = ARCFD/1000000./SMATX(2,IS1) AEF16100

$$CFPGL = \frac{ARCFD}{1000000Q_{IS1}} \quad \left[\frac{ft^3 air}{gal\ sewage}\right]$$

VAER = VAER*DMATX(16,N) AEF16200

$$VAER = VAER*ECF_a \quad [gal]$$

QR = QR*DMATX(14,N) AEF16300

$$QR = QR*ECF_p \quad [MGD]$$

AFS = SMATX(2,OS1)*1000./DMATX(8,N)*DMATX(13,N) AEF16400

$$AFS = \frac{1000\ Q_{OS1}*ECF_s}{GSS} \quad \left[\frac{ft^2}{1000}\right]$$

Pump efficiency - Current values used in program; each can be changed by the replacement on punched card.

PEFF = 0.70 For QR<1.44MGD AEF23800

PEFF = 0.74 For QR<10.08MGD AEF24100

PEFF = 0.83 For QR$\geq$10.08MGD AEF24300

References:

Smith, 1969

Patterson and Banker, 1971

5. Cost Functions.

Aerator

a. Capital cost

Function of VAER

X = ALOG(VAER*1000./7.48) AEF17000

$$X = \ln \frac{1000VAER}{7.48}$$

CCOST(N,1) = EXP(2.414380+.175682*X+.084742*X**2.-.002670*X**3.)*1000. AEF17100

$$CCOST = 1000e^{2.414380+0.175682X+0.084742X^2-0.002670X^3} \quad \text{[dollars]}$$

b. Operating manhours, maintenance manhours and materials/supplies costs

(1) Operating manhours AEF17800

OHRS = 0 [hrs/yr]

(2) Maintenance manhours AEF17900

XMHRS = 0 [hrs/yr]

(3) Total materials and supplies AEF18000

TMSU = 0 [dollars/yr]

c. Total operating and maintenance costs AEF18100

COSTO(N,1) = 0 [cents/1000gal]

Blower

a. Capital cost

Function of BSIZE

X = ALOG(BSIZE/1000.) AEF18700

$$X = \ln \frac{BSIZE}{1000}$$

CCOST(N,2) = EXP(4.145454+.633339*X+.031939*X**2.-.002419*X**3.)*1000. AEF18800

$$CCOST = 1000e^{4.145454+0.633339X+0.031939X^2-0.002419X^3} \quad \text{[dollars]}$$

b. Operating manhours, maintenance manhours and materials/supplies costs

Function of $BSIZE/ECF_b$

X = ALOG(BSIZE/1000./DMATX(15,N)) AEF19500

$$X = \ln \frac{BSIZE}{1000ECF_b}$$

(1) Operating manhours

```
OHRS = EXP(6.900586+.323725*X+.059093*X**2.-.004926*X**3.)          AEF20100
```

$$OHRS = e^{6.900586+0.323725X+0.059093X^2-0.004926X^3} \qquad [hrs/yr]$$

(2) Maintenance manhours

```
                                                                    AEF20200
XMHRS = EXP(6.169937+.294853*X+.175999X**2.-.040947*X**3.+.003300*X**4.)
```

$$XMHRS = e^{6.169937+0.294853X+0.175999X^2-0.040947X^3+0.003300X^4} \qquad [hrs/yr]$$

(3) Blower horsepower

```
HP = BSIZE/DMATX(15,N)*8.1*144./(33000.*.8)                         AEF20400
```

$$HP = \frac{BSIZE*8.1*144}{ECF_b*33000*0.8} \qquad [horsepower]$$

(4) Blower kilowatts

```
XKW = .8*HP                                                         AEF20500
```

$$XKW = \frac{BSIZE*8.1*144}{33000ECF_b} \qquad [kilowatts]$$

(5) Blower kilowatt years

```
XKWPY = XKW*24.*365.                                                AEF20600
```

$$XKWPY = 24XKW*365 \qquad [kw\ hr/yr]$$

(6) Energy cost

```
ECOST = XKWPY*DMATX(10,20)                                          AEF20700
```

$$ECOST = XKWPY*CKWH \qquad [dollars/yr]$$

(7) Service cost

```
SCOST = EXP(.621382+.482047*X)*1000.                                AEF20800
```

$$SCOST = 1000e^{0.621382+0.482047X} \qquad [dollars/yr]$$

c. Total operating and maintenance costs

```
COSTO(N,2) = ((OHRS+XMHRS)*DHR*(1.+PCT)+SCOST*WPI+ECOST)/SMATX(2,1)/3650.          AEF21300
```

$$COSTO = \frac{(OHRS+XMHRS)DHR(1+PCT)+(SCOST*WPI)+ECOST}{Q_{Plant\ Inf.}*3650} \qquad [cents/1000gal]$$

Sludge pumps

a. Capital cost

Function QR

```
X = ALOG(QR)                                                          AEF22000
```

$X = \ln QR$

```
CCOST(N,3) = EXP(3.481553+.377485*X+.093349*X**2.-.006222*X**3.)*1000.   AEF22100
```

$$CCOST = 1000e^{3.481553+0.377485X+0.093349X^2-0.006222X^3} \qquad [dollars]$$

b. Operating manhours, maintenance manhours and materials/supplies costs

Function of QR/ECF_p

```
X = ALOG(QR/DMATX(14,N))                                              AEF22800
```

$$X = \ln \frac{QR}{ECF_p}$$

(1) Operating manhours

```
OHRS = EXP(6.097269+.253066*X-.193659*X**2.+.078201*X**3.-.006680*X**4.)    AEF23400
```

$$OHRS = e^{6.097269+0.253066X-0.193659X^2+0.078201X^3-0.006680X^4} \qquad [hrs/yr]$$

(2) Maintenance manhours

```
XMHRS = EXP(5.911541-.013158*X+.076643*X**2.)                         AEF23600
```

$$XMHRS = e^{5.911541-0.013158X+0.076643X^2} \qquad [hrs/yr]$$

(3) Kilowatt hrs per year

`YRKW = QR*1000000.*HEAD/1440./3960./PEFF/.9*.7457*24.*365.` AEF24400

$$YRKW = \frac{1000000QR*HEAD*0.7457*24*365}{1440*3960PEFF*0.9}$$ [kw hr/yr]

(4) Energy cost

`ECOST = YRKW*DMATX(10,20)` AEF24500

$ECOST = YRKW*CKWH$ [dollars/yr]

(5) Service cost

`SCOST = EXP(5.851743+.301610*X+.197183*X**2.-.017962*X**3.)` AEF24600

$SCOST = e^{5.851743+0.301610X+0.197183X^2-0.017962X^3}$ [dollars/yr]

(6) Total materials and supplies

`TMSU = ECOST+SCOST*WPI` AEF24700

$TMSU = ECOST+(SCOST*WPI)$ [dollars/yr]

c. Total operating and maintenance costs

`COSTO(N,3) = ((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU)/SMATX(2,1)/3650.` AEF25200

$$COSTO = \frac{(OHRS+XMHRS)DHR(1+PCT)+TMSU}{Q_{Plant\ Inf.}*3650}$$ [cents/1000gal]

Final settling tank

a. Capital cost

Function of AFS

`X = ALOG(AFS)` AEF25800

$X = \ln AFS$

`CCOST(N,4) = EXP(3.716354+.389861*X+.084560*X**2.-.004718*X**3.)*1000.` AEF25900

$CCOST = 1000e^{3.716354+0.389861X+0.084560X^2-0.004718X^3}$ [dollars]

b. Operating manhours, maintenance manhours and materials/supplies costs

Function of AFS/ECF_s

```
X = ALOG(AFS/DMATX(13,N))                                        AEF26600
```

$$X = \ln \frac{AFS}{ECF_s} .$$

(1) Operating manhours

```
OHRS = EXP(5.846565+.254813*X+.113703*X**2.-.010942*X**3.)       AEF27200
```

$$OHRS = e^{5.846565+0.254813X+0.113703X^2-0.010942X^3} \qquad \text{[hrs/yr]}$$

(2) Maintenance manhours

```
XMHRS = EXP(5.273419+.228329*X+.122646*X**2.-.011672*X**3.)      AEF27300
```

$$XMHRS = e^{5.273419+0.228329X+0.122646X^2-0.011672X^3} \qquad \text{[hrs/yr]}$$

(3) Total materials and supplies

```
TMSU = EXP(5.669881+.750799*X)                                   AEF27400
```

$$TMSU = e^{5.669881+0.750799X} \qquad \text{[dollars/yr]}$$

c. Total operating and maintenance costs

```
COSTO(N,4) = ((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.   AEF27900
```

$$COSTO = \frac{(OHRS+XMHRS)DHR(1+PCT)+(TMSU*WPI)}{Q_{\text{Plant Inf.}}*3650} \qquad \text{[cents/1000gal]}$$

```
C
C               ACTIVATED SLUDGE - FINAL SETTLER
C               PROCESS IDENTIFICATION NUMBER   3
C
      SUBROUTINE AERFS
C
C
C               COMMON INITIAL STATEMENTS
C
      INTEGER OS1,OS2
      COMMON SMATX(20,30),TMATX(20,30),DMATX(20,20),OMATX(20,20),IP(20),
     1INP,J0,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),ACOST(20,5)
     2,TCOST(20,5),DHR,PCT,WPI,CLAND,DLAND,FLOW(25),POW(25),TKWHD(25)
C
C
C               PROCESS RELATIONSHIPS REQD. TO CALC. EFFLUENT STREAM
C               CHARACTERISTICS
C
      HEAD=DMATX(9,N)
      BOD2=SMATX(8,IS1)+SMATX(17,IS1)
      DBOD2=SMATX(17,IS1)
      CEDR=.18*1.047**(DMATX(3,N)-28.)
      CAER=DMATX(4,N)*1.047**(DMATX(3,N)-20.)
      SA=DMATX(2,N)/1000.
      TA=(BOD2-DMATX(1,N))/(DMATX(1,N)*CAER*SA*24.)
      VAER=SMATX(2,IS1)*TA
      XRSS=556.1*DMATX(8,N)**.4942/DMATX(2,N)**1.8165/(TA*24.)**.4386
      ALD=DMATX(10,N)*.87*SMATX(14,IS1)
      IF (ALD) 10,20,10
   10 PALS=1.305*SMATX(14,IS1)+3.*ALD
      GO TO 30
   20 PALS=0.
   30 ASMAX=DMATX(1,N)/XRSS/.685
      ASMIN=0.
      NAER=0
      IF (ASMAX-DMATX(2,N)) 50,50,40
   40 ASMAX=DMATX(2,N)
   50 XMLAS=(ASMAX+ASMIN)/2.
      FOOD=SMATX(8,IS1)+DBOD2
      FMAX=FOOD
      N1=1
      GO TO 110
   60 ERROR=FMAX-FMIN
      IF (ERROR-.1) 240,240,70
   70 FOOD=(FMAX+FMIN)/2.
   80 IF (FOOD-SMATX(17,IS1)) 90,90,100
   90 DBOD4=SMATX(17,IS1)-FOOD
      SBOD4=SMATX(8,IS1)
      GO TO 110
  100 SBOD4=(SMATX(8,IS1)+SMATX(17,IS1)-FOOD)*.7
      DBOD4=.233*SBOD4
  110 TEMP1=.50*FOOD/XMLAS-XRSS
      SMATX(2,OS2)=(SMATX(2,IS1)*TEMP1-CEDR*VAER)/(DMATX(7,N)-XRSS)
      SMATX(2,OS1)=SMATX(2,IS1)-SMATX(2,OS2)
      N1=N1+1
      IF (N1-2) 130,130,120
  120 TEMP2=XRSS*SMATX(2,OS1)+DMATX(7,N)*SMATX(2,OS2)
      XMLBS=SMATX(2,IS1)*SBOD4/TEMP2/.8
      SMATX(8,OS1)=(XMLAS*.685+XMLBS*.8)*XRSS
      SMATX(17,OS1)=DBOD4
      TBOD5=SMATX(8,OS1)+SMATX(17,OS1)
      GO TO 140
  130 TBOD5=XMLAS*XRSS*.685
  140 IF (TBOD5-DMATX(1,N)) 150,150,200
  150 IF (N1-3) 160,170,190
  160 FMIN=(CEDR*VAER/SMATX(2,IS1)+XRSS)*XMLAS/.50
      FOOD=FMIN
      GO TO 80
  170 WRITE (IO,180)
  180 FORMAT (///,10X,'MLASS DEMAND CANNOT BE ACHIEVED')
      IAERF=1
      GO TO 470
  190 FMAX=FOOD
      GO TO 60
  200 IF (N1-3) 210,60,230
  210 WRITE (IO,220)
  220 FORMAT (///,10X,'BOD5 DEMAND CANNOT BE ACHIEVED')
      IAERF=1
      GO TO 470
  230 FMIN=FOOD
      GO TO 60
  240 XMLNB=SMATX(4,IS1)*SMATX(2,IS1)*2.13/TEMP2
      XMLIS=SMATX(2,IS1)*(SMATX(7,IS1)+PALS)/TEMP2
      XMLDS=.12*SMATX(2,IS1)*FOOD/TEMP2-.185*XMLAS
      TEMP3=XMLAS+XMLBS+XMLNB+XMLDS+XMLIS
      TEMP4=TEMP3-DMATX(2,N)
      NAER=NAER+1
      IF (ABS(TEMP4)-5.) 310,310,250
  250 IF (25-NAER) 260,280,280
  260 WRITE (IO,270)
  270 FORMAT (///,10X,'MLSS DEMAND CANNOT BE ACHIEVED')
      IAERF=1
      GO TO 470
  280 IF (TEMP4) 290,290,300
  290 ASMIN=XMLAS
      GO TO 50
  300 ASMAX=XMLAS
      GO TO 50
C
C
C               EFFLUENT STREAM CALCULATIONS
C
  310 SMATX(3,OS1)=(XMLDS+XMLAS)*XRSS/2.46+(XMLBS+XMLNB)*XRSS/2.33
      SMATX(4,OS1)=XMLNB*XRSS/2.33+(XMLDS+.185*XMLAS)*XRSS/2.46
      TEMP5=XRSS*XMLAS/2.46
      SMATX(5,OS1)=.234*TEMP5+(SMATX(3,OS1)-TEMP5)/10.
      SMATX(6,OS1)=SMATX(3,OS1)*.01
      SMATX(7,OS1)=XMLIS*XRSS
      SMATX(9,OS1)=SMATX(3,OS1)*2.38
      SMATX(10,OS1)=SMATX(7,OS1)+SMATX(9,OS1)
      DO 320 I=3,10
  320 SMATX(I,OS2)=SMATX(I,OS1)*DMATX(7,N)/XRSS
      SMATX(11,OS1)=SMATX(12,IS1)+DBOD4/1.87
      SMATX(12,OS1)=SMATX(12,IS1)
      SMATX(13,OS1)=(SMATX(2,IS1)*(SMATX(5,IS1)+SMATX(13,IS1))-(SMATX(5,
     1OS1)*SMATX(2,OS1)+SMATX(5,OS2)*SMATX(2,OS2)))/(SMATX(2,OS1)+SMATX(
     22,OS2))
      SMATX(14,OS1)=(SMATX(2,IS1)*(SMATX(6,IS1)+SMATX(14,IS1))-(SMATX(6,
     1OS1)*SMATX(2,OS1)+SMATX(6,OS2)*SMATX(2,OS2)))/(SMATX(2,OS1)+SMATX(
     22,OS2))
      SMATX(15,OS1)=SMATX(15,IS1)
      DO 330 I=11,15
  330 SMATX(I,OS2)=SMATX(I,OS1)
      QR=(SMATX(2,IS1)*(1.-.50*FOOD/XMLAS)+CEDR*VAER)/(DMATX(7,N)-1.)
      RTURN=QR/SMATX(2,IS1)
      X4X3=(1.+RTURN)/RTURN/DMATX(7,N)
      DN3=SMATX(13,IS1)/(1.+RTURN)
      X3Y=DN3*.99/(X4X3-1.)
      CNIT=.18*EXP(.116*(DMATX(3,N)-15.))
      IF (X4X3) 340,340,350
  340 TTAN=0.
      GO TO 360
  350 TTAN=(1.+RTURN)*(ALOG(X4X3)+4.605/(DN3+X3Y))/CNIT
  360 VNIT=SMATX(2,IS1)*TTAN
      IF (VNIT-VAER) 370,370,380
  370 SMATX(16,OS1)=SMATX(16,IS1)+3.57*(SMATX(13,OS1)-SMATX(13,IS1))
      GO TO 390
  380 SMATX(16,OS1)=SMATX(16,IS1)
  390 SMATX(16,OS2)=SMATX(16,OS1)
      SMATX(17,OS2)=SMATX(17,OS1)
      SMATX(18,OS1)=SMATX(18,IS1)
      SMATX(18,OS2)=SMATX(18,IS1)
      SMATX(19,OS1)=SMATX(19,IS1)
      SMATX(19,OS2)=SMATX(19,IS1)
      SMATX(20,OS1)=SMATX(20,IS1)
      SMATX(20,OS2)=SMATX(20,IS1)
C
C
C           CALC. OF OUTPUT SIZES AND QUANTITIES
C
      DOSAT=(14.16-.3943*DMATX(3,N)+.007714*DMATX(3,N)**2-.0000646*DMATX
     1(3,N)**3)*1.221
      AEFF=DMATX(6,N)*(DOSAT-DMATX(5,N))*1.02**(DMATX(3,N)-20.)/DOSAT
      WFOOD=SMATX(2,IS1)*FOOD*8.33
      WAS=XMLAS*VAER*8.33
      ARCFD=(.577*WFOOD+1.16*CEDR*WAS)/AEFF/.232/.075
      WDN=(SMATX(2,OS1)*SMATX(13,OS1)+SMATX(2,OS2)*SMATX(13,OS2))*8.33
      IF (VNIT-VAER) 400,400,410
  400 ARCFD=ARCFD+4.6*WDN/AEFF/.232/.075
  410 BSIZE=DMATX(15,N)*ARCFD/1440.
      CFPGL=ARCFD/1000000./SMATX(2,IS1)
      VAER=VAER*DMATX(16,N)
      QR=QR*DMATX(14,N)
      AFS=SMATX(2,OS1)*1000./DMATX(8,N)*DMATX(13,N)
C
C
C           CALC. OF CAPITAL COSTS FOR AERATOR BASED ON DESIGN PLUS
C           EXCESS CAPACITY
C
      X=ALOG(VAER*1000./7.48)
      CCOST(N,1)=EXP(2.414380+.175682*X+.084742*X**2.-.002670*X**3.)*100
     10.
C
C
C           CALC. OF OPERATING COSTS FOR AERATOR BASED ON DESIGN
C           CAPACITY ALONE, DOES NOT INCLUDE EXCESS CAPACITY
C
      OHRS=0.
      XMHRS=0.
      TMSU=0.
      COSTO(N,1)=0.
C
C
C           CALC. OF CAPITAL COSTS FOR BLOWER BASED ON DESIGN PLUS
C           EXCESS CAPACITY
C
```

```
      X=ALOG(BSIZE/1000.)                                               AEF18700
      CCOST(N,2)=EXP(4.145454+.633339*X+.031939*X**2.-.002419*X**3.)*100AEF18800
     10.                                                                AEF18900
C                                                                       AEF19000
C                                                                       AEF19100
C             CALC. OF OPERATING COSTS FOR BLOWER BASED ON DESIGN       AEF19200
C             CAPACITY ALONE, DOES NOT INCLUDE EXCESS CAPACITY          AEF19300
C                                                                       AEF19400
      X=ALOG(BSIZE/1000./DMATX(15,N))                                   AEF19500
C                                                                       AEF19600
C                                                                       AEF19700
C                  CALC. OF OPERATING MANHOURS MAINTENANCE MANHOURS     AEF19800
C                  ELECTRICAL POWER AND SUPPLY COSTS                    AEF19900
C                                                                       AEF20000
      OHRS=EXP(6.900586+.325725*X+.059093*X**2.-.004926*X**3.)          AEF20100
      XMHRS=EXP(6.169937+.294853*X+.175999*X**2.-.040947*X**3.+.003300*XAEF20200
     1**4.)                                                             AEF20300
      HP=BSIZE/DMATX(15,N)*8.1*144./(33000.*.8)                         AEF20400
      XKW=.6*HP                                                         AEF20500
      XKWPY=XKW*24.*365.                                                AEF20600
      ECOST=XKWPY*DMATX(10,20)                                          AEF20700
      SCOST=EXP(.621382+.482047*X)*1000.                                AEF20800
C                                                                       AEF20900
C                                                                       AEF21000
C                  OPERATING COST EQUATION                              AEF21100
C                                                                       AEF21200
      COSTO(N,2)=((OHRS+XMHRS)*DHR*(1.+PCT)+SCOST*WPI+ECOST)/SMATX(2,1)/AEF21300
     13650.                                                             AEF21400
C                                                                       AEF21500
C                                                                       AEF21600
C             CALC. OF CAPITAL COSTS FOR SLUDGE PUMPS BASED ON DESIGN   AEF21700
C             PLUS EXCESS CAPACITY                                      AEF21800
C                                                                       AEF21900
      X=ALOG(QR)                                                        AEF22000
      CCOST(N,3)=EXP(3.481553+.377485*X+.093349*X**2.-.006222*X**3.)*100AEF22100
     10.                                                                AEF22200
C                                                                       AEF22300
C                                                                       AEF22400
C             CALC. OF OPERATING COSTS FOR SLUDGE PUMPS BASED ON        AEF22500
C             DESIGN CAPACITY ALONE, DOES NOT INCLUDE EXCESS CAPACITY   AEF22600
C                                                                       AEF22700
      X=ALOG(QR/DMATX(14,N))                                            AEF22800
C                                                                       AEF22900
C                                                                       AEF23000
C                  CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS    AEF23100
C                  AND MATERIALS AND SUPPLIES                           AEF23200
C                                                                       AEF23300
      OHRS=EXP(6.097269+.253066*X-.193659*X**2.+.078201*X**3.-.006680*X*AEF23400
     1*4.)                                                              AEF23500
      XMHRS=EXP(5.911541-.013158*X+.076643*X**2.)                       AEF23600
      IF (QR-1.44) 420,430,430                                          AEF23700
  420 PEFF=.70                                                          AEF23800
      GO TO 460                                                         AEF23900
  430 IF (QR-10.08) 440,450,450                                         AEF24000
  440 PEFF=.74                                                          AEF24100
      GO TO 460                                                         AEF24200
  450 PEFF=.83                                                          AEF24300
  460 YRKW=QR*1000000.*HEAD/1440./3960./PEFF/.9*.7457*24.*365.          AEF24400
      ECOST=YRKW*DMATX(10,20)                                           AEF24500
      SCOST=EXP(5.851743+.301610*X+.197183*X**2.-.017962*X**3.)         AEF24600
      TMSU=ECOST+SCOST*WPI                                              AEF24700
C                                                                       AEF24800
C                                                                       AEF24900
C                  OPERATING COST EQUATION                              AEF25000
C                                                                       AEF25100
```

```
      COSTO(N,3)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU)/SMATX(2,1)/3650.      AEF25200
C                                                                       AEF25300
C                                                                       AEF25400
C              CALC. OF CAPITAL COSTS FOR FINAL SETTLER BASED ON DESIGN AEF25500
C              PLUS EXCESS CAPACITY                                     AEF25600
C                                                                       AEF25700
      X=ALOG(AFS)                                                       AEF25800
      CCOST(N,4)=EXP(3.716354+.389861*X+.084560*X**2.-.004718*X**3.)*100AEF25900
     10.                                                                AEF26000
C                                                                       AEF26100
C                                                                       AEF26200
C              CALC. OF OPERATING COSTS FOR FINAL SETTLER BASED ON      AEF26300
C              DESIGN CAPACITY ALONE, DOES NOT INCLUDE EXCESS CAPACITY  AEF26400
C                                                                       AEF26500
      X=ALOG(AFS/DMATX(13,N))                                           AEF26600
C                                                                       AEF26700
C                                                                       AEF26800
C                    CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS  AEF26900
C                    AND MATERIALS AND SUPPLIES                         AEF27000
C                                                                       AEF27100
      OHRS=EXP(5.846565+.254813*X+.113703*X**2.-.010942*X**3.)          AEF27200
      XMHRS=EXP(5.273419+.228329*X+.122646*X**2.-.011672*X**3.)         AEF27300
      TMSU=EXP(5.669881+.750799*X)                                      AEF27400
C                                                                       AEF27500
C                                                                       AEF27600
C                    OPERATING COST EQUATION                            AEF27700
C                                                                       AEF27800
      COSTO(N,4)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.  AEF27900
C                                                                       AEF28000
C                                                                       AEF28100
C              ASSIGNMENT OF VALUES TO OMATX                            AEF28200
C                                                                       AEF28300
      OMATX(1,N)=BOD2                                                   AEF28400
      OMATX(2,N)=DOSAT                                                  AEF28500
      OMATX(3,N)=XRSS                                                   AEF28600
      OMATX(4,N)=AFS                                                    AEF28700
      OMATX(5,N)=CAER                                                   AEF28800
      OMATX(6,N)=CEDR                                                   AEF28900
      OMATX(7,N)=VAER                                                   AEF29000
      OMATX(8,N)=VNIT                                                   AEF29100
      OMATX(9,N)=XMLAS                                                  AEF29200
      OMATX(10,N)=XMLBS                                                 AEF29300
      OMATX(11,N)=XMLNB                                                 AEF29400
      OMATX(12,N)=XMLDS                                                 AEF29500
      OMATX(13,N)=XMLIS                                                 AEF29600
      OMATX(14,N)=FOOD                                                  AEF29700
      OMATX(15,N)=RTURN                                                 AEF29800
      OMATX(16,N)=CNIT                                                  AEF29900
      OMATX(17,N)=ARCFD                                                 AEF30000
      OMATX(18,N)=BSIZE                                                 AEF30100
      OMATX(19,N)=CFPGL                                                 AEF30200
      OMATX(20,N)=QR                                                    AEF30300
C                                                                       AEF30400
C                                                                       AEF30500
C              PROCESS ENERGY INDICES                                   AEF30600
C                                                                       AEF30700
      FLOW(N)=SMATX(2,IS1)                                              AEF30800
      POW(N)=3.                                                         AEF30900
  470 RETURN                                                            AEF31000
      END                                                               AEF31100
```

SECTION 5

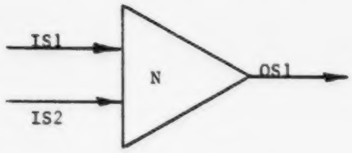
STREAM MIXER, MIX

Subroutine Identification Number 4

Stream Mixer, MIX

Rev. Date 8/1/77

1. Process symbol.



IS1: Primary input stream

IS2: Secondary input stream

OS1: Primary output stream

N: User assigned number to the process, must be zero for mixer

2. Input parameters and nominal values.

No input data.

3. Output parameters which are printed on computer output sheets.

No output data.

4. Theory and functions - FORTRAN statement followed by equivalent algebraic equation.

```
SMATX(2,OS 1) = SMATX(2,IS1)+SMATX(2,IS2)                                MIX01900
```

$$Q_{OS1} = Q_{IS1}+Q_{IS2} \quad [MGD]$$

```
TEMP1 = SMATX(2,IS1)/(SMATX(2,IS1)+SMATX(2,IS2))                         MIX02100
```

$$TEMP1 = \frac{Q_{IS1}}{Q_{IS1}+Q_{IS2}}$$

```
TEMP2 = SMATX(2,IS2)/(SMATX(2,IS1)+SMATX(2,IS2))                         MIX02200
```

$$TEMP2 = \frac{Q_{IS2}}{Q_{IS1}+Q_{IS2}}$$

```
SMATX(I,OS1) = TEMP1*SMATX(I,IS1)+TEMP2*SMATX(I,IS2)                      MIX02800
```

$$SMATX(I,OS1) = \frac{Q_{IS1}}{Q_{IS1}+Q_{IS2}} *SMATX(I,IS1) + \frac{Q_{IS2}}{Q_{IS1}+Q_{IS2}} *SMATX(I,IS2) \quad [mg/l]$$

where I = 3,20 i.e. SOC,SNBC,SON,SOP,SFM,SBOD,VSS,TSS,DOC,DNBC,DN,
DP,DFM,ALK,DBOD,NH3,NO3

5. Cost functions.

No cost functions.

```
C
C           STREAM MIXER
C           PROCESS IDENTIFICATION NUMBER   4
C
      SUBROUTINE MIX
C
C
C           COMMON INITIAL STATEMENTS
C
      INTEGER OS1,OS2
      COMMON SMATX(20,30),TMATX(20,30),DMATX(20,20),OMATX(20,20),IP(20),
     1INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),ACOST(20,5)
     2,TCOST(20,5),DHR,PCT,WPI,CLAND,DLAND,FLOW(25),POW(25),TKWHD(25)
C
C
C           PROCESS RELATIONSHIPS REQD. TO CALC. EFFLUENT STREAM
C           CHARACTERISTICS
C
      SMATX(2,OS1)=SMATX(2,IS1)+SMATX(2,IS2)
      IF (SMATX(2,OS1)) 10,30,10
   10 TEMP1=SMATX(2,IS1)/(SMATX(2,IS1)+SMATX(2,IS2))
      TEMP2=SMATX(2,IS2)/(SMATX(2,IS1)+SMATX(2,IS2))
C
C
C           EFFLUENT STREAM CALCULATIONS
C
      DO 20 I=3,20
   20 SMATX(I,OS1)=TEMP1*SMATX(I,IS1)+TEMP2*SMATX(I,IS2)
   30 RETURN
      END
```

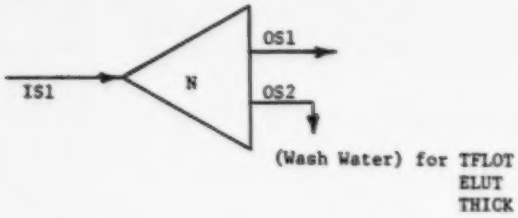
SECTION 6

STREAM SPLITTER, SPLIT

Subroutine Identification Number 5

Stream Splitter, SPLIT Rev. Date 8/1/77

1. Process symbol.



IS1: Primary input stream

OS1: Primary output stream

OS2: Secondary output stream

N: User assigned number to the process, must be zero for splitter

2. Input parameters and nominal values.

No input data.

3. Output parameters which are printed on computer output sheets.

No output data.

4. Theory and functions- FORTRAN statement followed by equivalent algebraic equation.

SMATX(2,OS1) = SMATX(2,IS1)-SMATX(2,OS2) SPL01900

$Q_{OS1} = Q_{IS1}-Q_{OS2}$ [MGD]

SMATX(I,OS1) = SMATX(I,IS1) SPL02500

SMATX(I,OS1) = SMATX(I,IS1) [mg/l]

where I = 3,20 i.e. SOC,SNBC,SON,SOP,SFM,SBOD,VSS,TSS,DOC, DNBC,DN,DP,DFM,ALK,DBOD,NH3,NO3

SMATX(I,OS2) = SMATX(I,IS1) SPL02600

SMATX(I,OS2) = SMATX(I,IS1) [mg/l]

5. Cost functions.

No cost function.

```
C
C             STREAM SPLITTER
C             PROCESS IDENTIFICATION NUMBER   5
C
      SUBROUTINE SPLIT
C
C
C             COMMON INITIAL STATEMENTS
C
      INTEGER OS1,OS2
      COMMON SMATX(20,30),TMATX(20,30),DMATX(20,20),OMATX(20,20),IP(20),
     1INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),ACOST(20,5)
     2,TCOST(20,5),DHR,PCT,WPI,CLAND,DLAND,FLOW(25),POW(25),TKWHD(25)
C
C
C             PROCESS RELATIONSHIPS REQD. TO CALC. EFFLUENT STREAM
C             CHARACTERISTICS
C
      SMATX(2,OS1)=SMATX(2,IS1)-SMATX(2,OS2)
C
C
C             EFFLUENT STREAM CALCULATIONS
C
      DO 10 I=3,20
      SMATX(I,OS1)=SMATX(I,IS1)
   10 SMATX(I,OS2)=SMATX(I,IS1)
      RETURN
      END
```

SECTION 7

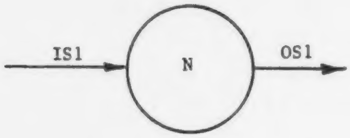
ANAEROBIC DIGESTER, DIG

Subroutine Identification Number 6

Anaerobic Digester, DIG

Rev. Date 8/1/77

1. Process symbol.



IS1: Sludge input stream

OS1: Sludge output stream

N: User assigned number to the process

2. Input parameters and nominal values.

DMATX(1,N) = TD	Digester dentention time, days. [15.]
DMATX(2,N) = TDIG	Sludge temperature in digester, degrees Centigrade. [33.]
DMATX(16,N) = ECF	Excess capacity factor. [1.3]

3. Output parameters which are printed on computer output sheets.

TD = DMATX(1,N)	
TDIG = DMATX(2,N)	
C1DIG = OMATX(1,N)	Rate constant for digester, [1/day].
C2DIG = OMATX(2,N)	Rate constant for biodegradable carbon, [1/day].
VDIG = OMATX(3,N)	Volume of digester facilities, [cu.ft./1000].
CH4 = OMATX(4,N)	Standard cubic feet of methane produced in the digester each day, [scf/day methane].
CO2 = OMATX(5,N)	Standard cubic feet of carbon dioxide produced in the digester each day, [scf/day carbon dioxide] .
CCOST	Capital cost, [dollars].
COSTO	Operating and maintenance cost, [cents/1000 gal].
ACOST	Amortization cost, [cents/1000 gal].
TCOST	Total treatment cost, [cents/1000 gal].
ECF	Excess capacity factor.

4. Theory and functions - FORTRAN statement followed by equivalent algebraic equation.

C1DIG = .28/EXP(.036*(35.-DMATX(2,N))) DIG02500

$$\mathrm{C1DIG} = \frac{0.28}{e^{0.036(35-\mathrm{TDIG})}} \qquad \left[\frac{1}{\mathrm{days}}\right]$$

C2DIG = 700.*EXP(.10*(35.-DMATX(2,N))) DIG02600

$$\mathrm{C2DIG} = 700e^{0.10(35-\mathrm{TDIG})} \qquad \left[\frac{\mathrm{mg/l}}{\mathrm{day}}\right]$$

DIG13 = C2DIG/(C1DIG*DMATX(1,N)-1.) DIG02700

$$\mathrm{DIG13} = \frac{\mathrm{C2DIG}}{\mathrm{C1DIG(TD)} - 1} \qquad [\mathrm{mg/l}]$$

DIG12 = SMATX(3,IS1)-SMATX(4,IS1)+SMATX(11,IS1)-SMATX(12,IS1) DIG02800

$$\mathrm{DIG12} = \mathrm{SOC}_{\mathrm{IS1}} - \mathrm{SNBC}_{\mathrm{IS1}} + \mathrm{DOC}_{\mathrm{IS1}} - \mathrm{DNBC}_{\mathrm{IS1}}$$

= total biodegradable carbon [mg/l]

TEMP1 = (DIG12-DIG13)/(SMATX(3,IS1)+SMATX(11,IS1)) DIG02900

$$\mathrm{TEMP1} = \frac{\mathrm{DIG12} - \mathrm{DIG13}}{\mathrm{SOC}_{\mathrm{IS1}} + \mathrm{DOC}_{\mathrm{IS1}}}$$

= fraction of biodegradable carbon remaining relative
to total organic carbon entering digester

SMATX(2,OS1) = SMATX(2,IS1) DIG03400

$$Q_{\mathrm{OS1}} = Q_{\mathrm{IS1}} \qquad [\mathrm{MGD}]$$

SMATX(3,OS1) = SMATX(4,IS1)+.75*DIG13 DIG03500

$$\mathrm{SOC}_{\mathrm{OS1}} = \mathrm{SNBC}_{\mathrm{IS1}} + 0.75(\mathrm{DIG13}) \qquad [\mathrm{mg/l}]$$

SMATX(4,OS1) = SMATX(4,IS1) DIG03600

$$\mathrm{SNBC}_{\mathrm{OS1}} = \mathrm{SNBC}_{\mathrm{IS1}} \qquad [\mathrm{mg/l}]$$

SMATX(5,OS1) = (1.-TEMP1)*SMATX(5,IS1) DIG03700

$$\mathrm{SON}_{\mathrm{OS1}} = (1-\mathrm{TEMP1})\ \mathrm{SON}_{\mathrm{IS1}} \qquad [\mathrm{mg/l}]$$

SMATX(6,OS1) = (1,-TEMP1)*SMATX(6,OS1) DIG03800

$$\mathrm{SOP}_{\mathrm{OS1}} = (1-\mathrm{TEMP1})\ \mathrm{SOP}_{\mathrm{IS1}} \qquad [\mathrm{mg/l}]$$

`SMATX(7,OS1) = SMATX(7,IS1)` DIG03900

$SFM_{OS1} = SFM_{IS1}$ [mg/l]

`SMATX(8,OS1) = (SMATX(3,OS1)-SMATX(4,OS1))*1.87` DIG04000

$SBOD_{OS1} = (SOC_{OS1} - SNBC_{OS1})1.87$ [mg/l]

`SMATX(9,OS1) = SMATX(3,OS1)*2.38` DIG04100

$VSS_{OS1} = (SOC_{OS1})2.38$ [mg/l]

`SMATX(10,OS1) = SMATX(9,OS1)+SMATX(7,OS1)` DIG04200

$TSS_{OS1} = VSS_{OS1} + SFM_{OS1}$ [mg/l]

`SMATX(11,OS1) = SMATX(12,IS1)+.25*DIG13` DIG04300

$DOC_{OS1} = DNBC_{IS1} + 0.25DIG13$ [mg/l]

`SMATX(12,OS1) = SMATX(12,IS1)` DIG04400

$DNBC_{OS1} = DNBC_{IS1}$ [mg/l]

`SMATX(13,OS1) = SMATX(13,IS1)+SMATX(5,IS1)*.65*TEMP1` DIG04500

$DN_{OS1} = DN_{IS1} + (SON_{IS1})0.65TEMP1$ [mg/l]

`SMATX(14,OS1) = SMATX(14,IS1) + TEMP1*SMATX(6,IS1)` DIG04600

$DP_{OS1} = DP_{OS1} + TEMP1(SOP_{IS1})$ [mg/l]

`SMATX(15,OS1) = SMATX(15,IS1)` DIG04700

$DFM_{OS1} = DFM_{IS1}$ [mg/l]

`SMATX(16,OS1) = SMATX(16,IS1)+(SMATX(13,OS1) - SMATX(13,IS1))*3.57` DIG04800

$ALK_{OS1} = ALK_{IS1} + 3.57(DN_{OS1} - DN_{IS1})$ [mg/l]

`SMATX(17,OS1) = (SMATX(11,OS1)-SMATX(12,OS1))*1.87` DIG04900

$DBOD_{OS1} = (DOC_{OS1} - DNBC_{OS1})\ 1.87$ [mg/l]

`CH4 = 163.85*(DIG12-DIG13)*SMATX(2,IS1)` DIG05700

$CH4 = 163.85(DIG12-DIG13)\ Q_{IS1}$ [scfd]

CO_2 `= 249.9*(DIG12-DIG13)*SMATX(2,IS1) -` CH_4 DIG05800

$CO_2 = 249.9(DIG12-DIG13)\ Q_{IS1} - CH4$ [scfd]

```
VDIG = SMATX(2,IS1)*DMATX(1,N)*1000/7.48*DMATX(16,N)                    DIG05900
```

$$VIDG = Q_{IS1} * TD * \frac{1000\ ECF}{7.48} \qquad [\frac{ft^3}{1000}]$$

References:

Patterson and Banker, 1971

Lawrence and McCarty, 1969

O'Rourke, 1968

Smith, 1969

5. Cost functions.

a. Capital cost

Function of VDIG

```
X = ln VDIG                                                             DIG06500
```

(1) Digester facilities less than 20000 ft^3

```
CCOST(N,1) = EXP(4.594215+.127244X-.004001*X**2.)*1000.                 DIG07200
```

$$CCOST = 1000e^{4.594215+0.127244X-0.004001X^2} \qquad [dollars]$$

(2) Digester facilities equal or greater than 20000 ft^3 DIG07900

```
CCOST(N,1) = EXP(7.679634-1.949689*X+.402610*X**2.-.018211*X**3.)*1000.
```

$$CCOST = 1000e^{7.679634-1.949689X+0.402610X^2-0.018211X^3} \qquad [dollars]$$

b. Operating manhours, maintenance manhours, and materials/supplies costs

Function of VDIG/ECF

```
X = ln (VDIG/ECF)                                                       DIG08600
```

(1) Digester facilities less than 20000 ft^3

(a) Operating manhours

```
OHRS = EXP(6.163803+0.166305*X-.012470*X**2.)                           DIG09400
```

$$OHRS = e^{6.163803+0.166305X-0.012470X^2} \qquad [hrs/yr]$$

(b) Maintenance manhours

```
XMHRS = EXP(5.726981+.113674*X)                                         DIG09500
```

$$XMHRS = e^{5.726981+0.113674X} \qquad [hrs/yr]$$

(c) Total materials and supplies

```
TMSU = EXP(6.531623+.198417*X+.021660*X**2.)                    DIG09600
```

$$TMSU = e^{6.531623+0.198417X+0.021660X^2} \quad \text{[dollars/yr]}$$

2. Digester facilities equal or greater than 20000 ft^3

(a) Operating manhours DIG10400

```
OHRS = EXP(9.129250-1.816736*X+.373282*X**2.-.017290*X**3.)
```

$$OHRS = e^{9.129250-1.816736X+0.373282X^2-0.017290X^3} \quad \text{[hrs/yr]}$$

(b) Maintenance manhours DIG10500

```
XMHRS = EXP(8.566752-1.768137*X+.363173*X**2.-.016620*X**3.)
```

$$XMHRS = e^{8.566752-1.768137X+0.363173X^2-0.016620X^3} \quad \text{[hrs/yr]}$$

(c) Total materials and supplies DIG10600

```
TMSU = EXP(8.702803-1.182711*X+.282691*X**2.-.013672*X**3.)
```

$$TMSU = e^{8.702803-1.182711X+0.282691X^2-0.013672X^3} \quad \text{[dollars/yr]}$$

c. Total operating and maintenance costs

```
COSTO(N,1) = ((OHRS+XMHRS)*DHR*(1+PCT)+TMSU*WPI)/SMATX(2,1)/3650.    DIG11100
```

$$COSTO = \frac{(OHRS+XMHRS)DHR(1+PCT)+TMSU(WPI)}{Q_{Plant\ Inf.} * 3650} \quad \text{[cents/1000 gal]}$$

```
C
C               SINGLE STAGE ANAEROBIC DIGESTION
C               PROCESS IDENTIFICATION NUMBER    6
C
      SUBROUTINE DIG
C
C
C               COMMON INITIAL STATEMENTS
C
      INTEGER OS1,OS2
      COMMON SMATX(20,30),TMATX(20,30),DMATX(20,20),OMATX(20,20),IP(20),
     1INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),ACOST(20,5)
     2,TCOST(20,5),DHR,PCT,WPI,CLAND,DLAND,FLOW(25),POW(25),TKWHD(25)
C
C
C               FORCING DIGESTER TO HAVE AT LEAST 10 DAYS DETENTION TIME
C
      IF (DMATX(1,N)-10.) 10,10,20
   10 DMATX(1,N)=10.
C
C
C               PROCESS RELATIONSHIPS REQD. TO CALC. EFFLUENT STREAM
C               CHARACTERISTICS
C
   20 C1DIG=.28/EXP(.036*(35.-DMATX(2,N)))
      C2DIG=700.*EXP(.10*(35.-DMATX(2,N)))
      DIG13=C2DIG/(C1DIG*DMATX(1,N)-1.)
      DIG12=SMATX(3,IS1)-SMATX(4,IS1)+SMATX(11,IS1)-SMATX(12,IS1)
      TEMP1=(DIG12-DIG13)/(SMATX(3,IS1)+SMATX(11,IS1))
C
C
C               EFFLUENT STREAM CALCULATIONS
C
      SMATX(2,OS1)=SMATX(2,IS1)
      SMATX(3,OS1)=SMATX(4,IS1)+.75*DIG13
      SMATX(4,OS1)=SMATX(4,IS1)
      SMATX(5,OS1)=(1.-TEMP1)*SMATX(5,IS1)
      SMATX(6,OS1)=(1.-TEMP1)*SMATX(6,IS1)
      SMATX(7,OS1)=SMATX(7,IS1)
      SMATX(8,OS1)=(SMATX(3,OS1)-SMATX(4,OS1))*1.87
      SMATX(9,OS1)=SMATX(3,OS1)*2.38
      SMATX(10,OS1)=SMATX(9,OS1)+SMATX(7,OS1)
      SMATX(11,OS1)=SMATX(12,IS1)+.25*DIG13
      SMATX(12,OS1)=SMATX(12,IS1)
      SMATX(13,OS1)=SMATX(13,IS1)+SMATX(5,IS1)*.65*TEMP1
      SMATX(14,OS1)=SMATX(14,IS1)+TEMP1*SMATX(6,IS1)
      SMATX(15,OS1)=SMATX(15,IS1)
      SMATX(16,OS1)=SMATX(16,IS1)+(SMATX(13,OS1)-SMATX(13,IS1))*3.57
      SMATX(17,OS1)=(SMATX(11,OS1)-SMATX(12,OS1))*1.87
      SMATX(18,OS1)=SMATX(18,IS1)
      SMATX(19,OS1)=SMATX(19,IS1)
      SMATX(20,OS1)=SMATX(20,IS1)
C
C
C               CALC. OF OUTPUT SIZES AND QUANTITIES
C
      CH4=163.85*(DIG12-DIG13)*SMATX(2,IS1)
      CO2=249.9*(DIG12-DIG13)*SMATX(2,IS1)-CH4
      VDIG=SMATX(2,IS1)*DMATX(1,N)*1000./7.48*DMATX(16,N)               DIG05900
C                                                                       DIG06000
C                                                                       DIG06100
C             CALC. OF CAPITAL COSTS BASED ON DESIGN PLUS EXCESS        DIG06200
C             CAPACITY                                                  DIG06300
C                                                                       DIG06400
      X=ALOG(VDIG)                                                      DIG06500
      IF (VDIG-20.) 30,40,40                                            DIG06600
C                                                                       DIG06700
C                                                                       DIG06800
C                       CALC. OF CAPITAL COSTS FOR SMALL DIG FACILITY, LESS DIG06900
C                       THAN 20000 CU. FT.                              DIG07000
C                                                                       DIG07100
   30 CCOST(N,1)=EXP(4.594215+.127244*X-.004001*X**2.)*1000.            DIG07200
      GO TO 50                                                          DIG07300
C                                                                       DIG07400
C                                                                       DIG07500
C                       CALC. OF CAPITAL COSTS FOR LARGE DIG FACILITY, EQUAL DIG07600
C                       OR GREATER THAN 20000 CU. FT.                   DIG07700
C                                                                       DIG07800
   40 CCOST(N,1)=EXP(7.679634-1.949689*X+.402610*X**2.-.018211*X**3.)*10DIG07900
     100.                                                               DIG08000
C                                                                       DIG08100
C                                                                       DIG08200
C             CALC. OF OPERATING COSTS BASED ON DESIGN CAPACITY ALONE,  DIG08300
C             DOES NOT INCLUDE EXCESS CAPACITY                          DIG08400
C                                                                       DIG08500
   50 X=ALOG(VDIG/DMATX(16,N))                                          DIG08600
      IF (VDIG-20.) 60,70,70                                            DIG08700
C                                                                       DIG08800
C                                                                       DIG08900
C                       CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS DIG09000
C                       AND MATERIALS AND SUPPLIES FOR DIG FACILITY, LESS DIG09100
C                       THAN 20000 CU. FT.                              DIG09200
C                                                                       DIG09300
   60 OHRS=EXP(6.163803+.166305*X-.012470*X**2.)                        DIG09400
      XMHRS=EXP(5.726981+.113674*X)                                     DIG09500
      TMSU=EXP(6.531623+.196417*X+.021660*X**2.)                        DIG09600
      GO TO 80                                                          DIG09700
C                                                                       DIG09800
C                                                                       DIG09900
C                       CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS DIG10000
C                       AND MATERIALS AND SUPPLIES FOR DIG FACILITY, EQUAL DIG10100
C                       OR GREATER THAN 20000 CU. FT.                   DIG10200
C                                                                       DIG10300
   70 OHRS=EXP(9.129250-1.816736*X+.373282*X**2.-.017290*X**3.)         DIG10400
      XMHRS=EXP(8.566752-1.768137*X+.363173*X**2.-.016620*X**3.)        DIG10500
      TMSU=EXP(8.702803-1.162711*X+.282691*X**2.-.013672*X**3.)         DIG10600
C                                                                       DIG10700
C                                                                       DIG10800
C                       OPERATING COST EQUATION                         DIG10900
C                                                                       DIG11000
   80 COSTO(N,1)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.  DIG11100
C                                                                       DIG11200
C                                                                       DIG11300
C             ASSIGNMENT OF VALUES TO OMATX                             DIG11400
C                                                                       DIG11500
      OMATX(1,N)=C1DIG                                                  DIG11600
      OMATX(2,N)=C2DIG                                                  DIG11700
      OMATX(3,N)=VDIG                                                   DIG11800
      OMATX(4,N)=CH4                                                    DIG11900
      OMATX(5,N)=CO2                                                    DIG12000
C                                                                       DIG12100
C                                                                       DIG12200
C             PROCESS ENERGY INDICES                                    DIG12300
C                                                                       DIG12400
```

```
      FLOW(N)=SMATX(2,IS1)                                              DIG12500
      POW(N)=6.                                                         DIG12600
      RETURN                                                            DIG12700
      END                                                               DIG12800
```

SECTION 8

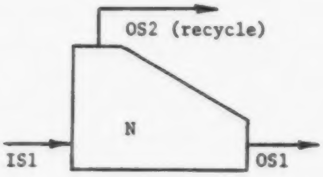
VACUUM FILTRATION, VACF

Subroutine Identification Number 7

Vacuum Filtration, VACF

Rev. Date 8/1/77

1. Process symbol.



IS1: Sludge input stream

OS1: Sludge cake output stream

OS2: Liquid recycle output stream

N: User assigned number to the process

2. Input parameters and nominal values.

DMATX (1,N) = VFL	Vacuum filter loading rate, gph/sq ft. [4.9]
DMATX (2,N) = HPWK	Hours per week that the vacuum filter is operated, hr/wk. [35.]
DMATX (3,N) = TSS	Total suspended solids concentration of OS2, mg/l. [200.]
DMATX (4,N) = IVACF	Program control: 0 = landfill disposal of sludge, 1 = incineration disposal of sludge. [1.]
DMATX (5,N) = FECL3	Dose of ferric chloride added to condition the sludge, lb/ton. [42.]
DMATX (6,N) = CAO	Dose of lime added to condition the sludge, lb/ton. [176.]
DMATX (7,N) = CFECL	Cost of ferric chloride, $/lb. [.064]
DMATX (8,N) = CCAO	Cost of lime, $/lb. [.0125]
DMATX (9,N) = DPOLY	Dose of polymer added to condition the sludge, lb/ton. [15.]
DMATX (10,N) = CPOLY	Cost of polymer, $/lb. [.33]
DMATX (16,N) = ECF	Excess capacity factor for the process. [1.]

3. Output parameters which are printed on computer output sheets.

IVACF = DMATX (4,N)

FECL3 = DMATX (5,N)

CAO = DMATX (6,N)

CFECL = DMATX (7,N)

CCAO = DMATX (8,N)

DPOLY = DMATX (9,N)

CPOLY = DMATX(10,N)

WP = OMATX(1,N)	Percentage of moisture in the filtered sludge.
AVF = OMATX(2,N)	Surface area of the vacuum filter, sq.ft.
PSDD = OMATX(3,N)	Amount of dry solids produced by the vacuum filter, lb/day.
CCOST	Capital cost, [dollars].
COSTO	Operating and maintenance costs,[cents/1000 gal].
ACOST	Amortization cost, [cents/1000 gal].
TCOST	Total treatment cost,[cents/1000 gal].
ECF	Excess capacity factor.

4. Theory and functions - FORTRAN statement followed by equivalent algebraic equation.

```
SMATX(7,IS1) = SMATX(7,IS1)+(FECL3+CAO+DPOLY)*SMATX(10,IS1)/2000.        VAC02900
```

$$SFM_{IS1} = SFM_{IS1} + \frac{(FECL3+CAO+DPOLY)TSS_{IS1}}{2000} \qquad [mg/l]$$

```
SMATX(10,IS1) = SMATX(10,IS1)+(FECL3+CAO+DPOLY)*SMATX(10,IS1)/2000.      VAC03000
```

$$TSS_{IS1} = TSS_{IS1} + \frac{(FECL3+CAO+DPOLY)TSS_{IS1}}{2000} \qquad [mg/l]$$

```
SMATX(10,OS2) = DMATX(3,N)                                               VAC03100
```

$$TSS_{OS2} = TSS \qquad [mg/l]$$

```
WP = 88./(SMATX(10,IS1)/10000.)**.123                                    VAC03200
```

$$WP = \frac{88}{\left[\frac{TSS_{IS1}}{10000}\right]^{0.123}} \qquad [mg/l]$$

```
SMATX(10,OS1) = (100.-WP)*10000.                                         VAC03300
```

$$TSS_{OS1} = 10000(100-WP) \qquad [mg/l]$$

```
SMATX(2,OS1) =(SMATX(2,IS1)*SMATX(10,IS1))/(SMATX(10,OS1)-SMATX(10,OS2))
```

$$Q_{OS1} = \frac{Q_{IS1}*TSS_{IS1}}{TSS_{OS1}-TSS_{OS2}} \qquad [mg/l]$$

VAC03400

SMATX(2,OS2) = SMATX(2,IS1)-SMATX(2,OS1) VAC03600

$$Q_{OS2} = Q_{IS1} - Q_{OS1} \qquad [mg/l]$$

TEMP2 = SMATX(10,OS1)/SMATX(10,IS1) VAC03700

$$TEMP2 = \frac{TSS_{OS1}}{TSS_{IS1}} \qquad [\text{no units}]$$

TEMP3 = SMATX(10,OS2)/SMATX(10,IS1) VAC03800

$$TEMP3 = \frac{TSS_{OS2}}{TSS_{IS1}} \qquad [\text{no units}]$$

SMATX(I,OS1) = TEMP2*SMATX(I,IS1) VAC04400

SMATX(I,OS1) = TEMP2*SMATX(I,IS1) [mg/l]

where I = 3,9 i.e. SOC,SNBC,SON,SOP,SFM,SBOD,VSS

SMATX(I,OS2) = TEMP3*SMATX(I,IS1) VAC04500

SMATX(I,OS2) = TEMP3*SMATX(I,IS1) [mg/l]

where I = 3,9

SMATX(I,OS1) = TEMP2*SMATX(I,IS1) VAC04700

SMATX(I,OS1) = TEMP2*SMATX(I,IS1) [mg/l]

where I = 11,17 i.e. DOC,DNBC,DN,DP,DFM,ALK,DBOD

SMATX(I,OS2) = SMATX(I,IS1) VAC04800

SMATX(I,OS2) = SMATX(I,IS1) [mg/l]

where I = 11,17

SMATX(18,OS1) = SMATX(18,IS1) VAC04900

$$NH3_{OS1} = NH3_{IS1} \qquad [mg/l]$$

SMATX(18,OS2) = SMATX(18,IS1) VAC05000

$$NH3_{OS2} = NH3_{IS1} \qquad [mg/l]$$

SMATX(19,OS1) = SMATX(19,IS1) VAC05100

$$NO3_{OS1} = NO3_{IS1} \qquad [mg/l]$$

SMATX(19,OS2) = SMATX(19,IS1) VAC05200

$NO3_{OS2} = NO3_{IS1}$ [mg/l]

SMATX(20,OS1) = SMATX(20,IS1) VAC05300

SMATX(20,OS1) = SMATX(20,IS1) Future parameter

SMATX(20,OS2) = SMATX(20,IS1) VAC05400

SMATX(20,OS2) = SMATX(20,IS1) Future parameter

SF = SMATX(10,IS1)/10000. VAC05900

$$SF = \frac{TSS_{IS1}}{10000}$$ [%]

SC = 100.-WP VAC06000

$SC = 100 - WP$ [%]

FVF = DMATX(1,N)/11.99/(1./SF-1./SC) VAC06100

$$FVF = \frac{VFL}{11.99\left[\frac{1}{SF} - \frac{1}{SC}\right]}$$ [lb/hr/ft^2]

AVF = SMATX(10,IS1)*SMATX(2,IS1)*58.31/FVF/DMATX(2,N)*DMATX(16,N) VAC06200

$$AVF = \frac{TSS_{IS1} * Q_{IS1} * 58.31 * ECF}{FVF * HPWK}$$ [ft^2]

PSDD = SMATX(10,IS1)*SMATX(2,IS1)*8.33 VAC06400

$PSDD = TSS_{IS1} * Q_{IS1} * 8.33$ [lb/day]

References:

Smith and Eilers, 1975

Patterson and Banker, 1971

5. Cost functions.

   a. Capital cost

      Function of AVF

      X = ALOG(AVF) VAC07000

      $X = \ln AVF$

```
CCOST(N,1) = EXP(3.288028+.194537*X+.038313*X**2.)*1000.                    VAC07100
```

$$CCOST = 1000e^{3.288028+0.194537\,X+0.038313X^2} \quad [\text{dollars}]$$

b. Operating manhours, maintenance manhours and materials/supplies costs

Function of PSDD

```
X = ALOG(PSDD*365./2000.)                                                    VAC07700
```

$$X = \ln \frac{365\ PSDD}{2000}$$

(1) Operating manhours

(a) For IVACF = 0 Landfill operation

```
OHRS = EXP(6.069419-.009894*X+.042699*X **2.)                                VAC08400
```

$$OHRS = e^{6.069419-0.009894X+0.042699X^2} \quad [\text{hrs/yr}]$$

(b) For IVACF = 1 Incineration operation

```
OHRS = EXP(3.714368+.850848*X-.074615*X**2.+.005085*X**3.)                   VAC09100
```

$$OHRS = e^{3.714368+0.850848X-0.074615X^2+0.005085X^3} \quad [\text{hrs/yr}]$$

(2) Maintenance manhours

```
XMHRS = EXP(4.306110-.093695*X+.047738*X**2.)                                VAC09700
```

$$XMHRS = e^{4.306110-0.093695X+0.047738X^2} \quad [\text{hrs/yr}]$$

(3) Supplies

```
SUPP = EXP(-3.113515+.718466*X)*1000.                                        VAC09800
```

$$SUPP = 1000e^{-3.113515+0.718466X} \quad [\text{dollars/yr}]$$

(4) Chemicals

```
CHEM = PSDD*365./2000.*(FECL3*CFECL+CAO*CCAO+DPOLY*CPOLY)                    VAC09900
```

$$CHEM = \frac{PSDD*365*[(FECL3*CFECL)+(CAO*CCAO)+(DPOLY*CPOLY)]}{2000} \quad [\text{dollars/yr}]$$

c. Total operating and maintenance costs VAC10400

```
COSTO(N,1) = ((OHRS+XMHRS)*DHR*(1.+PCT)+SUPP*WPI+CHEM)/SMATX(2,1)/3650.
```

$$\text{COSTO} = \frac{[(\text{OHRS}+\text{XMHRS})*\text{DHR}*(1+\text{PCT})]+(\text{SUPP}*\text{WPI})+\text{CHEM}}{Q_{\text{Plant Inf.}}*3650} \quad [\text{cents/1000 gal}]$$

Cost curves, Banker and Patterson page 50.

```
C
C           VACUUM FILTRATION
C           PROCESS IDENTIFICATION NUMBER   7
C
      SUBROUTINE VACF
C
C
C           COMMON INITIAL STATEMENTS
C
      INTEGER OS1,OS2
      COMMON SMATX(20,30),TMATX(20,30),DMATX(20,20),OMATX(20,20),IP(20),
     1INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),ACOST(20,5)
     2,TCOST(20,5),DHR,PCT,WPI,CLAND,DLAND,FLOW(25),POW(25),TKWHD(25)
C
C
C           ASSIGNMENT OF DESIGN VALUES TO CHEMICAL PARAMETERS
C
      FECL3=DMATX(5,N)
      CAO=DMATX(6,N)
      CFECL=DMATX(7,N)
      CCAO=DMATX(8,N)
      DPOLY=DMATX(9,N)
      CPOLY=DMATX(10,N)
C
C
C           PROCESS RELATIONSHIPS REQD. TO CALC. EFFLUENT STREAM
C           CHARACTERISTICS
C
      SMATX(7,IS1)=SMATX(7,IS1)+(FECL3+CAO+DPOLY)*SMATX(10,IS1)/2000.
      SMATX(10,IS1)=SMATX(10,IS1)+(FECL3+CAO+DPOLY)*SMATX(10,IS1)/2000.
      SMATX(10,OS2)=DMATX(3,N)
      WP=88./(SMATX(10,IS1)/10000.)**.123
      SMATX(10,OS1)=(100.-WP)*10000.
      SMATX(2,OS1)=(SMATX(2,IS1)*SMATX(10,IS1))/(SMATX(10,OS1)-SMATX(10,
     1OS2))
      SMATX(2,OS2)=SMATX(2,IS1)-SMATX(2,OS1)
      TEMP2=SMATX(10,OS1)/SMATX(10,IS1)
      TEMP3=SMATX(10,OS2)/SMATX(10,IS1)
C
C
C           EFFLUENT STREAM CALCULATIONS
C
      DO 10 I=3,9
      SMATX(I,OS1)=TEMP2*SMATX(I,IS1)
   10 SMATX(I,OS2)=TEMP3*SMATX(I,IS1)
      DO 20 I=11,17
      SMATX(I,OS1)=TEMP2*SMATX(I,IS1)
   20 SMATX(I,OS2)=SMATX(I,IS1)
      SMATX(18,OS1)=SMATX(18,IS1)
      SMATX(18,OS2)=SMATX(18,IS1)
      SMATX(19,OS1)=SMATX(19,IS1)
      SMATX(19,OS2)=SMATX(19,IS1)
      SMATX(20,OS1)=SMATX(20,IS1)
      SMATX(20,OS2)=SMATX(20,IS1)
C
C
C           CALC. OF OUTPUT SIZES AND QUANTITIES
C
```

```
      SF=SMATX(10,IS1)/10000.
      SC=100.-WP
      FVF=DMATX(1,N)/11.99/(1./SF-1./SC)
      AVF=SMATX(10,IS1)*SMATX(2,IS1)*58.31/FVF/DMATX(2,N)*DMATX(16,N)
      IVACF=DMATX(4,N)
      PSDD=SMATX(10,IS1)*SMATX(2,IS1)*8.33
C
C
C              CALC. OF CAPITAL COSTS BASED ON DESIGN PLUS EXCESS
C              CAPACITY
C
      X=ALOG(AVF)
      CCOST(N,1)=EXP(3.288028+.194537*X+.038313*X**2.)*1000.
C
C
C              CALC. OF OPERATING COSTS BASED ON DESIGN CAPACITY ALONE,
C              DOES NOT INCLUDE EXCESS CAPACITY
C
      X=ALOG(PSDD*365./2000.)
      IF (IVACF) 40,30,40
C
C
C                   CALC. OF OPERATING MANHOURS IF LANDFILL DISPOSAL IS
C                   USED
C
   30 OHRS=EXP(6.069419-.009894*X+.042699*X**2.)
      GO TO 50
C
C
C                   CALC. OF OPERATING MANHOURS IF INCINERATION DISPOSAL
C                   IS USED
C
   40 OHRS=EXP(3.714368+.850848*X-.074615*X**2.+.005085*X**3.)
C
C
C                   CALC. OF MAINTENANCE MANHOURS AND SUPPLIES AND
C                   CHEMICAL COSTS FOR VACF FACILITY
C
   50 XMHRS=EXP(4.306110-.093695*X+.047738*X**2.)
      SUPP=EXP(-3.113515+.718466*X)*1000.
      CHEM=PSDD*365./2000.*(FECL3*CFECL+CAO*CCAO+DPOLY*CPOLY)
C
C
C                   OPERATING COST EQUATION
C
      COSTO(N,1)=((OHRS+XMHRS)*DHR*(1.+PCT)+SUPP*WPI+CHEM)/SMATX(2,1)/36
     150.
C
C
C             ASSIGNMENT OF VALUES TO OMATX
C
      OMATX(1,N)=WP
      OMATX(2,N)=AVF
      OMATX(3,N)=PSDD
C
C
C             PROCESS ENERGY INDICES
C
      FLOW(N)=SMATX(2,IS1)
      POW(N)=7.
      RETURN
      END
```

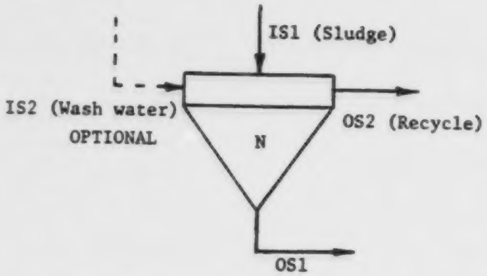
SECTION 9

GRAVITY THICKENING, THICK

Subroutine Identification Number 8

Gravity Thickening, THICK   Rev. Date 8/1/77

1. Process symbol.



IS1: Sludge input stream

IS2: Wash water input stream

OS1: Liquid output stream

OS2: Recycle output stream

N: User assigned number to the process

2. Input parameters and nominal values.

DMATX(1,N) = TRR	Solids recovery ratio for thickening. [.95]
DMATX(2,N) = TSS	Total suspended solids concentration of OS1, mg/l. [50,000.]
DMATX(3,N) = GTH	Design overflow rate for the thickener, gpd/sq ft. [700.]
DMATX(4,N) = GSTH	Design solids loading rate for the thickener, lb/day/sq ft. [8.]
DMATX(16,N) = ECF	Excess capacity factor for the process. [1.5]

3. Output parameters which are printed on computer output sheets.

TSS_{OS1} = DMATX(2,N)	
ATHM = OMATX(1,N)	Surface area of the gravity thickener, [sq. ft.]
WRT = OMATX(2,N)	Ratio of dilution stream flow in mgd/influent sludge stream flow in mgd.
CCOST	Capital cost, [dollars].
COSTO	Operating and maintenance cost, [cents/1000 gal].
ACOST	Amortization cost, [cents/1000 gal].

TCOST	Total treatment cost,[cents/1000 gal].
ECF	Excess capacity factor.

4. Theory and functions - FORTRAN statement followed by equivalent algebraic equation.

`SMAT(I) = 0` THI02100

where I = 1,20

`SMAT(I) = SMATX(I,IS2)` THI02400

`SMAT(I)=SMATX(I,IS2)` [MGD and mg/l]

where I = 1,20

i.e. I, Q, SOC, SNBC, SON, SOP, SFM, SBOD, VSS, TSS, DOC, DNBC, DN, DP, DFM, ALK, DBOD, NH3,NO3

`SMATX(2,OS1) = DMATX(1,N)*(SMATX(2,IS1)*SMATX(10,IS1)+SMAT(2)*SMAT(10))/SMATX(10,OS1)`

$$Q_{OS1} = \frac{TRR*[(Q_{IS1}*TSS_{IS1})+(Q_{IS2}*TSS_{IS2})]}{TSS_{OS1}}$$ [MGD] THI02600

`TEMP = DMATX(4,N)/DMATX(3,N)*1000000./8.33` THI02800

$$TEMP = \frac{1000000\ GSTH}{8.33\ GTH}$$ [mg/l]

`WRT = (SMATX(10,IS1)-TEMP)/(TEMP-SMAT(10))` THI03200

$$WRT = \frac{TSS_{IS1}-TEMP}{TEMP-TSS_{IS2}}$$ [mg/l]

`SMATX(2,IS2) = WRT*SMATX(2,IS1)` THI03300

$$Q_{IS2} = WRT*Q_{IS1}$$ [MGD]

`SMAT(2) = SMATX(2,IS2)` THI03400

$$SMAT(2) = Q_{IS2}$$ [MGD]

`SMATX(2,OS2) = SMATX(2,IS1)+SMAT(2)-SMATX(2,OS1)` THI03500

$$Q_{OS2} = Q_{IS1}+Q_{IS2}-Q_{OS1}$$ [MGD]

`TEMP = SMATX(2,IS1)*SMATX(10,IS1)+SMAT(2)*SMAT(10)` THI03600

$$TEMP = Q_{IS1}*TSS_{IS1}+Q_{IS2}*TSS_{IS2}$$ [MGD-mg/l]

`SMATX(10,OS2) = (TEMP-SMATX(2,OS1)*SMATX(10,OS1))/SMATX(2,OS2)` THI03700

$$TSS_{OS2} = \frac{TEMP-(Q_{OS1}*TSS_{OS1})}{Q_{OS2}}$$ [mg/l]

TEMP = TEMP/(SMATX(2,IS1)+SMAT(2)) THI03800

$$\mathrm{TEMP} = \frac{\mathrm{TEMP}}{Q_{IS1}+Q_{IS2}}$$ [mg/l]

TEMP1 = SMATX(10,OS1)/TEMP THI03900

$$\mathrm{TEMP1} = \frac{TSS_{OS1}}{\mathrm{TEMP}}$$ [no units]

TEMP2 = SMATX(10,OS2)/TEMP THI04000

$$\mathrm{TEMP2} = \frac{TSS_{OS2}}{\mathrm{TEMP}}$$ [no units]

TEMP3 = (SMATX(2,IS1)*SMATX(I,IS1)+SMAT(2)*SMAT(I))/(SMATX(2,IS1)+SMAT(2))

$$\mathrm{TEMP3} = \frac{(Q_{IS1}*\mathrm{SMATX}(I,IS1))+(Q_{IS2}*\mathrm{SMAT}(I))}{Q_{IS1}+Q_{IS2}}$$ [mg/l] THI04600

where I = 3,9

i.e. SOC,SNBC,SON,SOP,SFM,SBOD,VSS

SMATX(I,OS1) = TEMP1*TEMP3 THI04800

SMATX(I,OS1) = TEMP1 * TEMP3 [mg/l]

where I = 3,9

SMATX(I,OS2) = TEMP2 * TEMP3 THI04900

SMATX(I,OS2) = TEMP2*TEMP3 [mg/l]

where I = 3,9

SMATX(I,OS1) = (SMATX(I,IS1)*SMATX(2,IS1)+SMAT(I)*SMAT(2))/(SMATX(2,IS1)+SMAT(2))

$$\mathrm{SMATX}(I,OS1) = \frac{(\mathrm{SMATX}(I,IS1)*Q_{IS1})+(\mathrm{SMAT}(I)*Q_{IS2})}{Q_{IS1}+Q_{IS2}}$$ [mg/l] THI05100

where I = 11,20

i.e. DOC,DNBC,DN,DP.DFM,ALK,DBOD,NH3,NO3

SMATX(I,OS2) = SMATX(I,OS1) THI05300

SMATX(I,OS2) = SMATX(I,OS1) [mg/l]

where I = 11,20

ATH1 = (SMATX(2,OS2)+SMATX(2,OS1))*1000000./DMATX(3,N)*DMATX(16,N)

$$\mathrm{ATH1} = \frac{(Q_{OS2}+Q_{OS1})*1000000*ECF}{GTH}$$ [ft^2] THI05800

`ATH2 = SMATX(2,IS1)*SMATX(10,IS1)*8.33/DMATX(4,N)*DMATX(16,N)` THI06000

$$ATH2 = \frac{Q_{IS1}*TSS_{IS1}*8.33*ECF}{GSTH} \qquad [ft^2]$$

`ATHM = ATH2` [For ATH1 - ATH2 <0] THI06200

`ATHM = ATH1` [For ATH1 - ATH2 $\geq$0] THI06400

References:

Smith and Eilers, 1975

Patterson and Banker, 1971

5. Cost functions.

a. Capital cost

Function of ATHM

`X = ALOG(ATHM/1000.)` THI07000

$$X = \ln \frac{ATHM}{1000}$$

`CCOST(N,1) = EXP(3.725902+.397690*X+.075742*X**2.-.001977*X**3.-.000296*X**4.)*1000.` THI07100

$$CCOST = 1000e^{3.725902+0.397690X+0.075742X^2-0.001977X^3-0.000296X^4} \qquad [dollars]$$

b. Operating manhours, maintenance manhours and materials/supplies costs

Function of ATHM/ECF

`X = ALOG(ATHM/1000./DMATX(16,N))` THI07800

$$X = \ln \frac{ATHM}{1000ECF}$$

(1) For (EXP(X)-1<0)

(a) Operating manhours

OHRS = 350 [hrs/yr] THI08600

(b) Maintenance manhours

XMHRS = 190 [hrs/yr] THI08700

(c) Total materials and supplies

TMSU = 250 [dollars/yr] THI08800

(2) For (EXP(X)-1$\geq$0)

(a) Operating manhours

`OHRS = EXP(5.846565+.254813*X+.113703*X**2.-.010942*X**3.)` THI09600

$$OHRS = e^{5.846565+0.254813X+0.113703X^2-0.010942X^3} \qquad [hrs/yr]$$

(b) Maintenance manhours

```
XMHRS = EXP(5.273419+.228329*X+.122646*X**2.-.011672*X**3.)          THI09700
```

$$XMHRS = e^{5.273419+0.228329X+0.122646X^2-0.011672X^3} \qquad \text{[hrs/yr]}$$

(c) Total materials and supplies

```
TMSU = EXP(5.669881+.750799*X)                                        THI09800
```

$$TMSU = e^{5.669881+0.750799X} \qquad \text{[dollars/yr]}$$

c. Total operating and maintenance costs

```
COSTO(N,1) = ((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.   THI10300
```

$$COSTO = \frac{(OHRS+XMHRS)*DHR*(1+PCT)+(TMSU*WPI)}{Q_{\text{Plant Inf.}}*3650} \qquad \text{[cents/1000 gal]}$$

```
C
C           GRAVITY THICKENING
C           PROCESS IDENTIFICATION NUMBER   8
C
      SUBROUTINE THICK
C
C
C           COMMON INITIAL STATEMENTS
C
      INTEGER OS1,OS2
      DIMENSION SMAT(20)
      COMMON SMATX(20,30),TMATX(20,30),DMATX(20,20),OMATX(20,20),IP(20),
     1INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),ACOST(20,5)
     2,TCOST(20,5),DHR,PCT,WPI,CLAND,DLAND,FLOW(25),POW(25),TKWHD(25)
C
C
C           PROCESS RELATIONSHIPS REQD. TO CALC. EFFLUENT STREAM
C           CHARACTERISTICS
C
      DO 10 I=1,20
   10 SMAT(I)=0.
      IF (IS2) 40,40,20
   20 DO 30 I=1,20
   30 SMAT(I)=SMATX(I,IS2)
   40 SMATX(10,OS1)=DMATX(2,N)
      SMATX(2,OS1)=DMATX(1,N)*(SMATX(2,IS1)*SMATX(10,IS1)+SMAT(2)*SMAT(1
     10))/SMATX(10,OS1)
      TEMP=DMATX(4,N)/DMATX(3,N)*1000000./8.33
      IF (IS2) 60,50,60
   50 WRT=0.
      GO TO 70
   60 WRT=(SMATX(10,IS1)-TEMP)/(TEMP-SMAT(10))
      SMATX(2,IS2)=WRT*SMATX(2,IS1)
      SMAT(2)=SMATX(2,IS2)
   70 SMATX(2,OS2)=SMATX(2,IS1)+SMAT(2)-SMATX(2,OS1)
      TEMP=SMATX(2,IS1)*SMATX(10,IS1)+SMAT(2)*SMAT(10)
      SMATX(10,OS2)=(TEMP-SMATX(2,OS1)*SMATX(10,OS1))/SMATX(2,OS2)
      TEMP=TEMP/(SMATX(2,IS1)+SMAT(2))
      TEMP1=SMATX(10,OS1)/TEMP
      TEMP2=SMATX(10,OS2)/TEMP
C
C
C           EFFLUENT STREAM CALCULATIONS
C
      DO 80 I=3,9
      TEMP3=(SMATX(2,IS1)*SMATX(I,IS1)+SMAT(2)*SMAT(I))/(SMATX(2,IS1)+SM
     1AT(2))
      SMATX(I,OS1)=TEMP1*TEMP3
   80 SMATX(I,OS2)=TEMP2*TEMP3
      DO 90 I=11,20
      SMATX(I,OS1)=(SMATX(I,IS1)*SMATX(2,IS1)+SMAT(I)*SMAT(2))/(SMATX(2,
     1IS1)+SMAT(2))
   90 SMATX(I,OS2)=SMATX(I,OS1)
C
C
C           CALC. OF OUTPUT SIZES AND QUANTITIES
C
      ATH1=(SMATX(2,OS2)+SMATX(2,OS1))*1000000./DMATX(3,N)*DMATX(16,N)
      IF (IS2) 120,100,120
  100 ATH2=SMATX(2,IS1)*SMATX(10,IS1)*8.33/DMATX(4,N)*DMATX(16,N)
      IF (ATH1-ATH2) 110,120,120
  110 ATHM=ATH2
      GO TO 130
  120 ATHM=ATH1
C
C
C            CALC. OF CAPITAL COSTS BASED ON DESIGN PLUS EXCESS
C            CAPACITY
C
  130 X=ALOG(ATHM/1000.)
      CCOST(N,1)=EXP(3.725902+.397690*X+.075742*X**2.-.001977*X**3.-.000
     1296*X**4.)*1000.
C
C
C            CALC. OF OPERATING COSTS BASED ON DESIGN CAPACITY ALONE,
C            DOES NOT INCLUDE EXCESS CAPACITY
C
      X=ALOG(ATHM/1000./DMATX(16,N))
      IF (EXP(X)-1.) 140,150,150
C
C
C                  CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS
C                  AND MATERIALS AND SUPPLIES FOR THICK FACILITY,
C                  LESS THAN 1000 SQ. FT.
C
  140 OHRS=350.
      XMHRS=190.
      TMSU=250.
      GO TO 160
C
C
C                  CALC.OF OPERATING MANHOURS, MAINTENANCE MANHOURS
C                  AND MATERIALS AND SUPPLIES FOR THICK FACILITY,
C                  EQUAL OR GREATER THAN 1000 SQ. FT.
C
  150 OHRS=EXP(5.846565+.254813*X+.113703*X**2.-.010942*X**3.)
      XMHRS=EXP(5.273419+.228329*X+.122646*X**2.-.011672*X**3.)
      TMSU=EXP(5.669881+.750799*X)
C
C
C                  OPERATING COST EQUATION
C
  160 COSTO(N,1)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.
C
C
C            ASSIGNMENT OF VALUES TO OMATX
C
      OMATX(1,N)=ATHM
      OMATX(2,N)=WRT
C
C
C            PROCESS ENERGY INDICES
C
      FLOW(N)=SMATX(2,IS1)
      POW(N)=8.
      RETURN
      END
```

SECTION 10

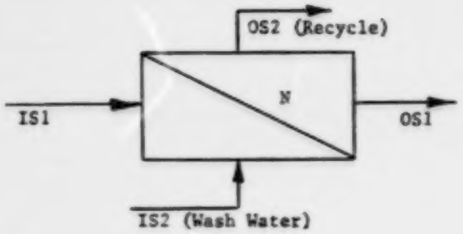
ELUTRIATION, ELUT

Subroutine Identification Number 9

Elutriation, ELUT

Rev. Date 8/1/77

1. Process symbol.



IS1: Sludge input stream

IS2: Wash water input stream

OS1: Sludge output stream

OS2: Recycle output stream

N: User assigned number to the process

2. Input parameters and nominal values.

DMATX(1,N) = ERR	Solids recovery ratio for elutriation. [.76]
DMATX(2,N) = TSS	Total suspended solids concentration of OS1, mg/1. [60,000.]
DMATX(3,N) = WRE	Wash water ratio for elutriation. [3.]
DMATX(4,N) = GE	Design overflow rate for elutriation, gpd/sq ft. [800.]
DMATX(5,N) = GES	Design solids loading rate for elutriation, lb/day/sq ft. [9.]
DMATX(16,N) = ECF	Excess capacity factor for the process. [1.5]

3. Output parameters which are printed on computer output sheets.

ERR = DMATX(1,N)	
TSS = DMATX(2,N)	
WRE = DMATX(3,N)	
GE = DMATX(4,N)	
GES = DMATX(5,N)	
AE = OMATX(1,N)	Surface area of the elutriation tank, sq. ft.
CCOST	Capital cost, [dollars]
COSTO	Operating and maintenance cost, [cents/1000 gal]
ACOST	Amortization cost, [cents/1000 gal]
TCOST	Total treatment cost, [cents/1000 gal]
ECF	Excess capacity factor.

4. Theory and functions - FORTRAN statement followed by equivalent algebraic equation.

```
SMATX(10,OS1) = DMATX(2,N)                          ELU01900
```

$$TSS_{OS1} = TSS \quad [mg/l]$$

```
SMATX(2,IS2) = DMATX(3,N)*SMATX(2,IS1)              ELU02000
```

$$Q_{IS2} = WRE * Q_{IS1} \quad [MGD]$$

```
AE1 = SMATX(2,IS1)*1000000./DMATX(4,N)              ELU04500
```

$$AE1 = \frac{Q_{IS1} * 1000000}{GE} \qquad [ft^2]$$

```
AE2 = SMATX(2,IS1)*SMATX(10,IS1)*8.33/DMATX(5,N)                    ELU04600
```

$$AE2 = \frac{Q_{IS1} * TSS_{IS1} * 8.33}{GES} \quad [ft^2]$$

```
AE = AE1*DMATX(16,N)            If (AE1-AE2)>0                      ELU04800
```

$$AE = AE1 * ECF \quad [ft^2]$$

```
AE = AE2*DMATX(16,N)            If (AE1-AE2)≤0                      ELU05000
```

$$AE = AE2 * ECF \quad [ft^2]$$

```
SMATX(2,OS1)=DMATX(1,N)*SMATX(2,IS1)*SMATX(10,IS1)/SMATX(10,OS1)    ELU02100
```

$$Q_{OS1} = \frac{ERR * Q_{IS1} * TSS_{IS1}}{TSS_{OS1}} \quad [MGD]$$

```
SMATX(2,OS2)=SMATX(2,IS1)+SMATX(2,IS2)-SMATX(2,OS1)                 ELU02200
```

$$Q_{OS2} = Q_{IS1} + Q_{IS2} - Q_{OS1} \quad [MGD]$$

```
TEMP = SMATX(2,IS1)*SMATX(10,IS1)+SMATX(2,IS2)*SMATX(10,IS2)        ELU02300
```

$$TEMP = [Q_{IS1}*TSS_{IS1}] + [Q_{IS2}*TSS_{IS2}] \quad [MGD\cdot mg/1]$$

```
SMATX(10,OS2)=(TEMP-SMATX(2,OS1)*SMATX(10,OS1))/SMATX(2,OS2)        ELU02400
```

$$TSS_{OS2} = \frac{TEMP - [Q_{OS1}*TSS_{OS1}]}{Q_{OS2}} \quad [mg/1]$$

```
TEMP = TEMP/(SMATX(2,IS1)+SMATX(2,IS2))                             ELU02500
```

$$TEMP = \frac{TEMP}{Q_{IS1}+Q_{IS2}} \quad [mg/1]$$

```
TEMP1  = SMATX(10,OS1)/TEMP                                         ELU02600
```

$$TEMP1 = \frac{TSS_{OS1}}{TEMP} \quad [no\ units]$$

TEMP2 = SMATX(10,OS2)/TEMP ELU02700

$$\mathrm{TEMP2} = \frac{\mathrm{TSS}_{\mathrm{OS2}}}{\mathrm{TEMP}} \quad \text{[no units]}$$

TEMP3 = (SMATX(2,IS1)*SMATX(I,IS1)+SMATX(2,IS2)*SMATX(I,IS2))/(SMATX(2,IS1)+SMATX(2,IS2)) ELU03300

$$\mathrm{TEMP3} = \frac{[Q_{\mathrm{IS1}} * \mathrm{SMATX(I,IS1)}] + [Q_{\mathrm{IS2}} * \mathrm{SMATX(I,IS2)}]}{Q_{\mathrm{IS1}} + Q_{\mathrm{IS2}}} \quad \text{[mg/1]}$$

where I = 3,9 i.e. SOC,SNBC,SON,SOP,SFM,SBOD,VSS

SMATX(I,OS1) = TEMP1 * TEMP3 ELU03500

SMATX(I,OS1) = TEMP1 * TEMP3 [mg/1]

where I = 3,9

i.e. SOC,SNBC,SON,SOP,SFM,SBOD,VSS

SMATX(I,OS2) = TEMP2 * TEMP3 ELU03600

SMATX(I,OS2) = TEMP2 * TEMP3 [mg/1]

where I = 3,9

SMATX(I,OS1) = (SMATX(I,IS1)*SMATX(2,IS1)+SMATX(I,IS2)*SMATX(2,IS2))/(SMATX(2,IS1)+SMATX(2,IS2)) ELU03800

$$\mathrm{SMATX(I,OS1)} = \frac{(\mathrm{SMATX(I,IS1)} * Q_{\mathrm{IS1}}) + (\mathrm{SMATX(I,IS2)} * Q_{\mathrm{IS2}})}{Q_{\mathrm{IS1}} + Q_{\mathrm{IS2}}} \quad \text{[mg/1]}$$

where I = 11,20 i.e. DOC,DNBC,DN,DP,DFM,ALK,DBOD,NH3,NO3

SMATX(I,OS2) = SMATX(I,OS1) ELU04000

SMATX(I,OS2) = SMATX(I,OS1) [mg/1]

where I = 11,20.

References:

Smith and Eilers, 1975

Patterson and Banker, 1971

5. **Cost functions.**

a. **Capital cost**

Function of AE

`X = ALOG(AE/1000.)` ELU05600

$$X = \ln \frac{AE}{1000}$$

`CCOST(N,1) = EXP(3.725902+.397690*X+.075742*X**2.-.001977*X**3.-.000296*X**4.)*1000.`

$$CCOST = 1000e^{3.725902+0.397690X+0.075742X^2-0.001977X^3-0.000296X^4} \quad \text{[dollars]}$$

ELU05700

b. **Operating manhours, maintenance manhours and materials/supplies costs**

Function of AE/ECF

`X = ALOG(AE/1000./DMATX(16,N))` ELU06400

$$X = \ln \frac{AE}{1000*ECF}$$

(1) Operating manhours

(a) $EXP(X)<1$ ELU06500

OHRS = 350. [hrs/yr] ELU07200

(b) $EXP(X)\geq 1$ ELU06500

`OHRS = EXP(5.846565+.254813*X+.113703*X**2.-.010942*X**3.)` ELU08200

$$OHRS = e^{5.846565+0.254813X+0.113703X^2-0.010942X^3} \quad \text{[hrs/yr]}$$

(2) Maintenance manhours

(a) $EXP(X)<1$ ELU06500

XMHRS = 190. [hrs/yr] ELU07300

(b) $EXP(X)\geq 1$ ELU06500

`XMHRS = EXP(5.273419+.228329*X+.122646*X**2.-.011672*X**3.)` ELU08300

$$XMHRS = e^{5.273419+0.228329X+0.122646X^2-0.011672X^3} \quad \text{[hrs/yr]}$$

(3) Total materials and supplies

(a) EXP(X)<1 ELU06500

TMSU = 250 [dollars/yr] ELU07400

(b) $EXP(X)\geq 1$ ELU06500

TMSU = EXP(5.669881+.750799*X) ELU08400

$$TMSU = e^{5.669881+0.750799X} \quad [dollars/yr]$$

c. Total operating and maintenance costs

COSTO(N,1) = ((OHRS+XMHRS)*DHR*(1+PCT)+TMSU*WPI)/SMATX(2,1)/3650. ELU08900

$$COSTO = \frac{(OHRS+XMHRS)DHR(1+PCT)+(TMSU*WPI)}{Q_{Plant\ Inf.} *3650} \quad [cents/1000\ gal]$$

```
C
C               ELUTRIATION
C               PROCESS IDENTIFICATION NUMBER   9
C
      SUBROUTINE ELUT
C
C
C               COMMON INITIAL STATEMENTS
C
      INTEGER OS1,OS2
      COMMON SMATX(20,30),TMATX(20,30),DMATX(20,20),OMATX(20,20),IP(20),
     1INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),ACOST(20,5)
     2,TCOST(20,5),DHR,PCT,WPI,CLAND,DLAND,FLOW(25),POW(25),TKWHD(25)
C
C
C               PROCESS RELATIONSHIPS REQD. TO CALC. EFFLUENT STREAM
C               CHARACTERISTICS
C
      SMATX(10,OS1)=DMATX(2,N)
      SMATX(2,IS2)=DMATX(3,N)*SMATX(2,IS1)
      SMATX(2,OS1)=DMATX(1,N)*SMATX(2,IS1)*SMATX(10,IS1)/SMATX(10,OS1)
      SMATX(2,OS2)=SMATX(2,IS1)+SMATX(2,IS2)-SMATX(2,OS1)
      TEMP=SMATX(2,IS1)*SMATX(10,IS1)+SMATX(2,IS2)*SMATX(10,IS2)
      SMATX(10,OS2)=(TEMP-SMATX(2,OS1)*SMATX(10,OS1))/SMATX(2,OS2)
      TEMP=TEMP/(SMATX(2,IS1)+SMATX(2,IS2))
      TEMP1=SMATX(10,OS1)/TEMP
      TEMP2=SMATX(10,OS2)/TEMP
C
C
C               EFFLUENT STREAM CALCULATIONS
C
      DO 10 I=3,9
      TEMP3=(SMATX(2,IS1)*SMATX(I,IS1)+SMATX(2,IS2)*SMATX(I,IS2))/(SMATX
     1(2,IS1)+SMATX(2,IS2))
      SMATX(I,OS1)=TEMP1*TEMP3
   10 SMATX(I,OS2)=TEMP2*TEMP3
      DO 20 I=11,20
      SMATX(I,OS1)=(SMATX(I,IS1)*SMATX(2,IS1)+SMATX(I,IS2)*SMATX(2,IS2))
     1/(SMATX(2,IS1)+SMATX(2,IS2))
   20 SMATX(I,OS2)=SMATX(I,OS1)
C
C
C               CALC. OF OUTPUT SIZES AND QUANTITIES
C
      AE1=SMATX(2,IS1)*1000000./DMATX(4,N)
      AE2=SMATX(2,IS1)*SMATX(10,IS1)*8.33/DMATX(5,N)
      IF (AE1-AE2) 40,40,30
   30 AE=AE1*DMATX(16,N)
      GO TO 50
   40 AE=AE2*DMATX(16,N)
C
C
C               CALC. OF CAPITAL COSTS BASED ON DESIGN PLUS EXCESS
C               CAPACITY
C
   50 X=ALOG(AE/1000.)
      CCOST(N,1)=EXP(3.725902+.397690*X+.075742*X**2.-.001977*X**3.-.000
     11296*X**4.)*1000.
```

```
C
C
C                 CALC. OF OPERATING COSTS BASED ON DESIGN CAPACITY ALONE,
C                 DOES NOT INCLUDE EXCESS CAPACITY
C
      X=ALOG(AE/1000./DMATX(16,N))
      IF (EXP(X)-1.) 60,70,70
C
C
C                        CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS
C                        AND MATERIALS AND SUPPLIES FOR ELUT FACILITY, LESS
C                        THAN 1000 SQ. FT.
C
   60 OHRS=350.
      XMHRS=190.
      TMSU=250.
      GO TO 80
C
C
C                        CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS
C                        AND MATERIALS AND SUPPLIES FOR ELUT FACILITY, EQUAL
C                        OR GREATER THAN 1000 SQ. FT.
C
   70 OHRS=EXP(5.846565+.254813*X+.113703*X**2.-.010942*X**3.)
      XMHRS=EXP(5.273419+.228329*X+.122646*X**2.-.011672*X**3.)
      TMSU=EXP(5.669881+.750799*X)
C
C
C                        OPERATING COST EQUATION
C
   80 COSTO(N,1)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*API)/SMATX(2,1)/3650.
C
C
C                 ASSIGNMENT OF VALUES TO OMATX
C
      OMATX(1,N)=AE
C
C
C                 PROCESS ENERGY INDICES
C
      FLOW(N)=SMATX(2,IS1)
      POW(N)=9.
      RETURN
      END
```

SECTION 11

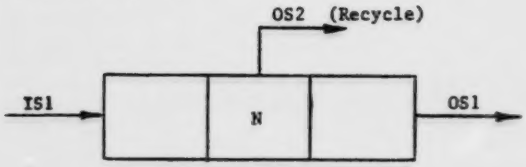
SAND DRYING BEDS, SBEDS

Subroutine Identification Number 10

Sand Drying Beds, SBEDS

Rev. Date 8/1/77

1. Process symbol.



IS1: Sludge input stream

OS1: Sludge cake stream

OS2: Recycle output stream

N: User assigned number to the process

2. Input parameters and nominal values.

DMATX(1,N) = SOUT	Percent solids of OS1, fraction, [.35].
DMATX(2,N) = TSS	Total suspended solids concentration of OS2, mg/l, [50.].
DMATX(16,N) = ECF	Excess capacity factor for the process, [1.5].

3. Output parameters which are printed on computer output sheets.

SOUT = DMATX(1,N)	
TSS = DMATX(2,N)	
ASB = OMATX(1,N)	Area of the sludge drying beds, [sq. ft.].
CCOST	Capital cost, [dollars].
COSTO	Operating and maintenance cost, [cents/1000 gal].
ACOST	Amortization cost , [cents/1000 gal].
TCOST	Total treatment cost , [cents/1000 gal].
ECF	Excess capacity factor.

4. Theory and functions - FORTRAN statement followed by equivalent algebraic equation.

`SMATX(2,OS2) = SMATX(2,IS1)` SBE01800

$$Q_{OS2} = Q_{IS1} \quad [\mathrm{MGD}]$$

`SMATX(10,OS2) = DMATX(2,N)` SBE01900

$$TSS_{OS2} = TSS \quad [\mathrm{mg/l}]$$

`TEMP = SMATX(10,OS2)/SMATX(10,IS1)` SBE02000

$$TEMP = \frac{TSS_{OS2}}{TSS_{IS1}} \quad [\text{no units}]$$

`SMATX(I,OS2) = TEMP*SMATX(I,IS1)` SBE02200

SMATX(I,OS2) = TEMP*SMATX(I,IS1) [mg/l]

where I = 3,9 i.e. SOC,SNBC,SON,SOP,SFM,SBOD,VSS

`SMATX(I,OS2) = SMATX(I,IS1)` SBE02400

SMATX(I,OS2) = SMATX(I,IS1) [mg/l]

where I = 11,20 i.e. DOC,DNBC,DN,DP,DFM,ALK,DBOD,NH3,NO3

`SF = SMATX(10,IS1)/10000.` SBE02900

$$SF = \frac{TSS_{IS1}}{10000} \quad [\%]$$

`SC = DMATX(1,N)*100.` SBE03000

$$SC = SOUT*100 \quad [\%]$$

`FSB = (29.84*SF-33.3)/SC` SBE03100

$$FSB = \frac{29.84SF-33.3}{SC} \quad [\text{lb dry solids applied/ft}^2\text{/30 days}]$$

`TEMP = SMATX(2,IS1)*SMATX(10,IS1)*249.9` SBE03200

$$TEMP = Q_{IS1}*TSS_{IS1}*249.9 \quad [\text{lb dry solids/30 days}]$$

`ASB = TEMP/FSB*DMATX(16,N)` SBE03300

$$ASB = \frac{TEMP*ECF}{FSB} \quad [\mathrm{ft}^2]$$

`PSDD = SMATX(10,IS1)*SMATX(2,IS1)*8.33` SBE03400

$$PSDD = TSS_{IS1}*Q_{IS1}*8.33 \quad [\text{lb dry solids applied/day}]$$

Reference: Smith and Eilers, 1975
Patterson and Banker, 1971

5. Cost functions. (Cost curves, Patterson and Banker pages 48,102,103)

a. Capital cost

Function of ASB

```
X = ALOG(ASB/1000.)                                    SBE04000
```

$$X = \ln\left(\frac{ASB}{1000}\right)$$

```
CCOST(N,1) = EXP(1.971125+.083841*X+.146751*X**2.-.007718*X**3.)*1000.     SBE04100
```

$$CCOST = 1000e^{1.971125+0.083841X+0.146751X^2-0.007718X^3} \quad \text{[dollars]}$$

b. Operating manhours, maintenance manhours, and materials/supplies costs

Function of PSDD

```
X = ALOG(PSDD*365./2000.)                              SBE04800
```

$$X = \ln\left(\frac{365PSDD}{2000}\right) \quad \text{[ln(tons applied/year)]}$$

(1) Operating manhours

```
OHRS = EXP(6.345052-.476780*X+.101319*X**2.)           SBE05400
```

$$OHRS = e^{6.345052-0.476780X+0.101319X^2} \quad \text{[hrs/yr]}$$

(2) Maintenance manhours

```
XMHRS = EXP(4.290089-.098293*X+.075453*X**2.)          SBE05500
```

$$XMHRS = e^{4.290089-0.098293X+0.075453X^2} \quad \text{[hrs/yr]}$$

(3) Total materials and supplies

```
TMSU = EXP(.693148+1.000000*X)                         SBE05600
```

$$TMSU = e^{0.693148+X} \quad \text{[dollars/yr]}$$

c. Total operating and maintenance costs

```
COSTO(N,1) = ((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.
                                                       SBE06100
```

$$COSTO = \frac{[(OHRS+XMHRS)*DHR*(1+PCT)]+[TMSU*WPI]}{Q_{Plant\ Inf.}*3650} \quad \text{[cents/1000 gal]}$$

```
C
C            SAND DRYING BEDS
C            PROCESS IDENTIFICATION NUMBER  10
C
      SUBROUTINE SBEDS
C
C
C            COMMON INITIAL STATEMENTS
C
      INTEGER OS1,OS2
      COMMON SMATX(20,30),TMATX(20,30),DMATX(20,20),OMATX(20,20),IP(20),
     1INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),ACOST(20,5)
     2,TCOST(20,5),DHR,PCT,WPI,CLAND,DLAND,FLOW(25),POW(25),TKWHD(25)
C
C
C            EFFLUENT STREAM CALCULATIONS
C
      SMATX(2,OS2)=SMATX(2,IS1)
      SMATX(10,OS2)=DMATX(2,N)
      TEMP=SMATX(10,OS2)/SMATX(10,IS1)
      DO 10 I=3,9
   10 SMATX(I,OS2)=TEMP*SMATX(I,IS1)
      DO 20 I=11,20
   20 SMATX(I,OS2)=SMATX(I,IS1)
C
C
C            CALC. OF OUTPUT SIZES AND QUANTITIES
C
      SF=SMATX(10,IS1)/10000.
      SC=DMATX(1,N)*100.
      FSB=(29.84*SF-33.3)/SC
      TEMP=SMATX(2,IS1)*SMATX(10,IS1)*249.9
      ASB=TEMP/FSB*DMATX(16,N)
      PSDD=SMATX(10,IS1)*SMATX(2,IS1)*8.33
C
C
C            CALC. OF CAPITAL COSTS BASED ON DESIGN PLUS EXCESS
C            CAPACITY
C
      X=ALOG(ASB/1000.)
      CCOST(N,1)=EXP(1.971125+.083841*X+.146751*X**2.-.007718*X**3.)*100
     10.
C
C
C            CALC. OF OPERATING COSTS BASED ON DESIGN CAPACITY ALONE,
C            DOES NOT INCLUDE EXCESS CAPACITY
C
      X=ALOG(PSDD*365./2000.)
C
C
C                  CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS
C                  AND MATERIALS AND SUPPLIES
C
      OHRS=EXP(6.345052-.476780*X+.101319*X**2.)
      XMHRS=EXP(4.290089-.098293*X+.075453*X**2.)
      TMSU=EXP(.693148+1.000000*X)
C
C
```

```
C                 OPERATING COST EQUATION                                  SBE05900
C                                                                          SBE06000
      COSTO(N,1)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.     SBE06100
C                                                                          SBE06200
C                                                                          SBE06300
C           ASSIGNMENT OF VALUES TO OMATX                                  SBE06400
C                                                                          SBE06500
      OMATX(1,N)=ASB                                                       SBE06600
C                                                                          SBE06700
C                                                                          SBE06800
C           PROCESS ENERGY INDICES                                         SBE06900
C                                                                          SBE07000
      FLOW(N)=SMATX(2,IS1)                                                 SBE07100
      POW(N)=10.                                                           SBE07200
      RETURN                                                               SBE07300
      END                                                                  SBE07400
```

SECTION 12

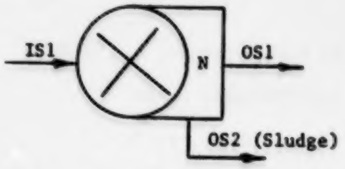
TRICKLING FILTER - FINAL SETTLER, TRFS

Subroutine Identification Number 11

Trickling Filter - Final Settler, TRFS

Rev. Date 8/1/77

1. Process symbol.



IS1: Liquid input stream
OS1: Liquid output stream
OS2: Sludge output stream
N: User assigned number to the process

2. Input parameters and nominal values.

DMATX(1,N) = BOD	Demand concentration of 5-day BOD in the final effluent from the trickling filter process. [26.]
DMATX(2,N) = DEGC	Water temperature, degrees Centigrade.[20.]
DMATX(3,N) = HQ	Hydraulic loading on the filter, based on sewage flow and not recycly, mgd/acre,[10.]
DMATX(4,N) = SAREA	Specific surface area of the filter, sq ft/cu ft. [10.]
DMATX(5,N) = URSS	Ratio of solids concentration in OS2 (underflow stream) from the final settler to the total solids concentration in the filter effluent.[2.]
DMATX(6,N) = XRSS	Ratio of solids concentration in the final settler effluent to the solids concentration in the filter effluent.[.6]
DMATX(7,N) = RECYCL	Trickling filter recycle ratio.[1.]
DMATX(8,N) = GSS	Design overflow rate for the final settler, gpd/sq ft.[2000.]
DMATX(9,N) = HEAD	Pumping head of the sludge return pumps, ft.[30.]
DMATX(14,N) = ECF	Excess capacity factor fot the sludge return pumps.[1.5]
DMATX(15,N) = ECF	Excess capacity factor for the final settler.[1.2]
DMATX(16,N) = ECF	Excess capacity factor for the filter [1.2]

3. Output parameters which are printed on computer output sheets.

BOD = DMATX(1,N)

DEGC = DMATX(2,N)	
HQ = DMATX(3,N)	
SAREA = DMATX(4,N)	
URSS = DMATX(5,N)	
XRSS = DMATX(6,N)	
RECYCL = DMATX(7,N)	
GSS = DMATX(8,N)	
HEAD = DMATX(9,N)	
AFS = OMATX(1,N)	Surface area of the final settler, sq ft/1000.
VOL = OMATX(2,N)	Trickling filter total volume, cu ft.
FAREA = OMATX(3,N)	Area of the face of the filter, sq ft.
DEPTH = OMATX(4,N)	Depth of the trickling filter, ft.
CCOST	Capital cost,[dollars]
COSTO	Operating and maintenance cost,[cents/1000gal]
ACOST	Amortization cost,[cents/1000gal]
TCOST	Total treatment cost,[cents/1000gal]
ECF	Excess capacity factor

4. Theory and functions - FORTRAN statement followed by equivalent algebraic equation.

BODIN = SMATX(8,IS1)+SMATX(17,IS1) TRF02000

$BODIN = SBOD_{IS1}+DBOD_{IS1}$ [mg/1]

BETA = .0245*1.035**(DMATX(2,N)-20.) TRF02100

$BETA = 0.0245*[1.035]^{DEGC-20}$ [constant]

XN = .91-6.45/DMATX(4,N) TRF02200

$XN = 0.91- \frac{6.45}{SAREA}$ [constant]

FAREA = SMATX(2,IS1)/DMATX(3,N)*43560. TRF08500

$FAREA = \frac{Q_{IS1}*43560}{HQ}$ [ft^2]

Q6 = DMATX(7,N)*SMATX(2,IS1) TRF02300

$Q6 = RECYCL*Q_{IS1}$ [MGD]

```
RHQ = ((DMATX(7,N)+1.)*DMATX(3,N))**XN                                   TRF02400
```

$$\mathrm{RHQ} = [(\mathrm{RECYCL}+1)*\mathrm{HQ}]^{\mathrm{XN}} \qquad [\mathrm{MGAD}^{xn}]$$

```
BOD = (SMATX(17,IS1)+DMATX(6,N)*SMATX(8,IS1))/DMATX(1,N)                 TRF02500
```

$$\mathrm{BOD} = \frac{\mathrm{DBOD}_{\mathrm{IS1}}+(\mathrm{XRSS}*\mathrm{SBOD}_{\mathrm{IS1}})}{\mathrm{BOD}_{\mathrm{OS1}}} \qquad [\text{no units}]$$

```
DEPTH = RHQ*ALOG((BOD+DMATX(7,N))/(DMATX(7,N)+1.))/(BETA*DMATX(4,N))     TRF02600
```

$$\mathrm{DEPTH} = \frac{\mathrm{RHQ}}{\mathrm{BETA}*\mathrm{SAREA}}*\ln\frac{\mathrm{BOD}+\mathrm{RECYCL}}{1+\mathrm{RECYCL}} \qquad [\mathrm{ft}]$$

```
XPO = EXP(BETA*DMATX(4,N)*DEPTH/RHQ)                                     TRF02700
```

$$\mathrm{XPO} = e^{\frac{\mathrm{BETA}*\mathrm{SAREA}*\mathrm{DEPTH}}{\mathrm{RHQ}}}$$

```
BODO = BODIN/(XPO*(DMATX(7,N)*(1.-1./XPO)+1.))                           TRF02800
```

$$\mathrm{BODO} = \frac{\mathrm{BODIN}}{\mathrm{XPO}*[\mathrm{RECYCL}*(1-\frac{1}{\mathrm{XPO}})+1]} \qquad [\mathrm{mg/l}]$$

```
DBODO = SMATX(17,IS1)/(XPO*(DMATX(7,N)*(1.-1./XPO)+1.))                  TRF02900
```

$$\mathrm{DBODO} = \frac{\mathrm{DBOD}_{\mathrm{IS1}}}{\mathrm{XPO}*[\mathrm{RECYCL}*(1-\frac{1}{\mathrm{XPO}})+1]} \qquad [\mathrm{mg/l}]$$

```
SBOD4 = BODO-DBODO                                                       TRF03000
```

$$\mathrm{SBOD4} = \frac{\mathrm{BODIN}-\mathrm{DBOD}_{\mathrm{IS1}}}{\mathrm{XPO}*[\mathrm{RECYCL}*(1-\frac{1}{\mathrm{XPO}})+1]} \qquad [\mathrm{mg/l}]$$

```
SBOD5 = SBOD4*DMATX(6,N)                                                 TRF03100
```

$$\mathrm{SBOD5} = \mathrm{SBOD4}*\mathrm{XRSS} \qquad [\mathrm{mg/l}]$$

```
BETAN = .00307*1.141**(DMATX(2,N)-20.)                                   TRF03200
```

$$\mathrm{BETAN} = 0.00307*[1.141]^{\mathrm{DEGC}-20} \qquad [\text{empirical parameter}]$$

```
XPON = EXP(BETAN*DMATX(4,N)*DEPTH/RHQ)                                   TRF03300
```

$$XPON = e^{\frac{BETAN*SAREA*DEPTH}{RHQ}}$$ [empirical parameter]

```
SON4 = SMATX(5,IS1)*SBOD4/SMATX(8,IS1)                                   TRF03400
```

$$SON4 = \frac{SON_{IS1}*SBOD4}{SBOD_{IS1}}$$ [mg/l]

```
DN4 = (SMATX(13,IS1)+SMATX(5,IS1)-SON4)/(XPON+(XPON-1.)*DMATX(7,N))     TRF03500
```

$$DN4 = \frac{DN_{IS1}+SON_{IS1}-SON4}{XPON+(XPON-1)*RECYCL}$$ [mg/l]

```
DN5 = DN4                                                                TRF03600
```

$$DN5 = \frac{DN_{IS1}+SON_{IS1}-SON4}{XPON+(XPON-1)*RECYCL}$$ [mg/l]

```
SON5 = SON4*DMATX(6,N)                                                   TRF03700
```

$$SON5 = SON4*XRSS$$ [mg/l]

```
SMATX(2,OS1) = SMATX(2,IS1)*(1.-DMATX(5,N))/(DMATX(6,N)-DMATX(5,N))     TRF04200
```

$$Q_{OS1} = \frac{Q_{IS1}*(1-URSS)}{XRSS-URSS}$$ [MGD]

```
SMATX(2,OS2) = SMATX(2,IS1)*(1.-DMATX(6,N))/(DMATX(5,N)-DMATX(6,N))     TRF04300
```

$$Q_{OS2} = \frac{Q_{IS1}*(1-XRSS)}{URSS-XRSS}$$ [MGD]

```
SMATX(4,OS1) = SMATX(4,IS1)*DMATX(6,N)                                   TRF04400
```

$$SNBC_{OS1} = SNBC_{IS1}*XRSS$$ [mg/l]

```
SMATX(4,OS2) = SMATX(4,IS1)*DMATX(5,N)                                   TRF04500
```

$$SNBC_{OS2} = SNBC_{IS1}*URSS$$ [mg/l]

```
SMATX(5,OS1) = SON5                                                      TRF04600
```

$$SON_{OS1} = SON5$$ [mg/l]

SMATX(5,OS2) = SON4*DMATX(5,N) TRF04700

$$SON_{OS2} = SON4*URSS$$

SMATX(6,OS1) = SMATX(6,IS1)*DMATX(6,N)*SBOD4/SMATX(8,IS1) TRF04800

$$SOP_{OS1} = \frac{SOP_{IS1}*XRSS*SBOD4}{SBOD_{IS1}} \qquad [mg/l]$$

SMATX(6,OS2) = SMATX(6,IS1)*DMATX(5,N)*SBOD4/SMATX(8,IS1) TRF04900

$$SOP_{OS2} = \frac{SOP_{IS1}*URSS*SBOD4}{SBOD_{IS1}} \qquad [mg/l]$$

SMATX(7,OS1) = SMATX(7,IS1)*DMATX(6,N) TRF05000

$$SFM_{OS1} = SFM_{IS1}*XRSS \qquad [mg/l]$$

SMATX(7,OS2) = SMATX(7,IS1)*DMATX(5,N) TRF05100

$$SFM_{OS2} = SFM_{IS1}*URSS \qquad [mg/l]$$

SMATX(8,OS1) = SBOD4*DMATX(6,N) TRF05200

$$SBOD_{OS1} = SBOD4*XRSS \qquad [mg/l]$$

SMATX(8,OS2) = SBOD4*DMATX(5,N) TRF05300

$$SBOD_{OS2} = SBOD4*URSS \qquad [mg/l]$$

SMATX(9,OS1) = SBOD4*DMATX(6,N)+SON5+SMATX(4,IS1)*DMATX(6,N) TRF05400

$$VSS_{OS1} = (SBOD4*XRSS)+SON5+(SNBC_{IS1}*XRSS) \qquad [mg/l]$$

SMATX(9,OS2) = SBOD4*DMATX(5,N)+SON4*DMATX(5,N)+SMATX(4,IS1)*DMATX(5,N) TRF05500

$$VSS_{OS2} = URSS*(SBOD4+SON4+SNBC_{IS1}) \qquad [mg/l]$$

`SMATX(10,OS1) = SMATX(9,OS1)+SMATX(7,OS1)+SMATX(6,OS1)` TRF05700

$TSS_{OS1} = VSS_{OS1}+SFM_{OS1}+SOP_{OS1}$ [mg/l]

`SMATX(10,OS2) = SMATX(9,OS2)+SMATX(7,OS2)+SMATX(6,OS2)` TRF05800

$TSS_{OS2} = VSS_{OS2}+SFM_{OS2}+SOP_{OS2}$ [mg/l]

`SMATX(12,OS1) = SMATX(12,IS1)` TRF05900

$DNBC_{OS1} = DNBC_{IS1}$ [mg/l]

`SMATX(12,OS2) = SMATX(12,IS1)` TRF06000

$DNBC_{OS2} = DNBC_{IS1}$ [mg/l]

`SMATX(13,OS1) = DN5` TRF06100

$DN_{OS1} = DN5$ [mg/l]

`SMATX(13,OS2) = DN5` TRF06200

$DN_{OS2} = DN5$ [mg/l]

`SMATX(14,OS1) = SMATX(14,IS1)+SMATX(6,IS1)*(1.-SBOD4/SMATX(8,IS1))` TRF06300

$DP_{OS1} = DP_{IS1}+SOP_{IS1}*(1-\frac{SBOD4}{SBOD_{IS1}})$ [mg/l]

`SMATX(14,OS2) = SMATX(14,OS1)` TRF06400

$DP_{OS2} = DP_{OS1}$ [mg/l]

`SMATX(15,OS1) = SMATX(15,IS1)` TRF06500

$DFM_{OS1} = DFM_{IS1}$ [mg/l]

`SMATX(15,OS2) = SMATX(15,IS1)` TRF06600

$DFM_{OS2} = DFM_{IS1}$ [mg/l]

```
SMATX(16,OS1) = SMATX(16,IS1)                                        TRF06700
```

$$ALK_{OS1} = ALK_{IS1} \qquad [mg/l]$$

```
SMATX(16,OS2) = SMATX(16,IS1)                                        TRF06800
```

$$ALK_{OS2} = ALK_{IS1} \qquad [mg/l]$$

```
SMATX(17,OS1) = DBODO                                                TRF06900
```

$$DBOD_{OS1} = DBODO \qquad [mg/l]$$

```
SMATX(17,OS2) = SMATX(17,OS1)                                        TRF07000
```

$$DBOD_{OS2} = DBODO \qquad [mg/l]$$

```
SMATX(3,OS1) = (SBOD5+1.87*SMATX(4,OS1))/1.87                        TRF07100
```

$$SOC_{OS1} = \frac{SBOD5+(1.87*SNBC_{OS1})}{1.87} \qquad [mg/l]$$

```
SMATX(3,OS2) = (SMATX(8,OS2)+1.87*SMATX(4,OS2))/1.87                 TRF07200
```

$$SOC_{OS2} = \frac{SBOD_{OS2}+(1.87*SNBC_{OS2})}{1.87} \qquad [mg/l]$$

```
SMATX(11,OS1) = (DBODO+1.87*SMATX(12,OS1))/1.87                      TRF07300
```

$$DOC_{OS2} = \frac{DBODO+(1.87*DNBC_{OS1})}{1.87} \qquad [mg/l]$$

```
SMATX(11,OS2) = SMATX(11,OS1)                                        TRF07400
```

$$DOC_{OS2} = DOC_{OS1} \qquad [mg/l]$$

```
SMATX(18,OS1) = SMATX(18,IS1)                                        TRF07500
```

$$NH3_{OS1} = NH3_{IS1} \qquad [mg/l]$$

```
SMATX(18,OS2) = SMATX(18,IS1)                                        TRF07600
```

$$NH3_{OS2} = NH3_{IS1} \qquad [mg/l]$$

SMATX(19,OS1) = SMATX(19,IS1) TRF07700

$NO3_{OS1} = NO3_{IS1}$ [mg/l]

SMATX(19,OS2) = SMATX(19,IS1) TRF07800

$NO3_{OS2} = NO3_{IS1}$ [mg/l]

SMATX(20,OS1) = SMATX(20,IS1) TRF07900

Future parameter [mg/l]

SMATX(20,OS2) = SMATX(20,IS1) TRF08000

Future parameter [mg/l]

PCR = (BODIN-DMATX(1,N))*100./BODIN TRF08600

$$PCR = \frac{(BODIN-BOD)*100}{BODIN}$$ [%]

AFS = SMATX(2,IS1)*1000./DMATX(8,N)*DMATX(15,N) TRF08700

$$AFS = \frac{Q_{IS1}*1000*ECF}{GSS}$$ [ft^2/1000]

VOL = FAREA*DEPTH*DMATX(16,N) TRF08800

$VOL = FAREA*DEPTH*ECF$ [ft^3]

References

Roesler and Smith, 1969

5. Cost functions.

Trickling filter

a. Capital cost

Function of VOL

X = ALOG(VOL/1000.) TRF09400

$$X = \ln \frac{VOL}{1000}$$

```
CCOST(N,1) = EXP(2.924951+.036285*X+.114673*X**2.-.004587*X**3.)*1000.     TRF09500
```

$$CCOST = 1000e^{2.924951+0.036285X+0.114673X^2-0.004587X^3}$$ [dollars]

b. Operating manhours, maintenance manhours, and materials/supplies costs

Function of Q_{IS1}/HQ

```
X = ALOG(SMATX(2,IS1)/DMATX(3,N)*43560./1000.)                             TRF10200
```

$$X = \ln \frac{Q_{IS1}*43560}{HQ*1000}$$ $[\ln \frac{ft^2}{1000}]$

(1) Operating manhours

```
OHRS = EXP(4.536510-.095731*X+.173718*X**2.-.010114*X**3.)                 TRF10800
```

$$OHRS = e^{4.536510-0.095731X+0.173718X^2-0.010114X^3}$$ [hrs/yr]

(2) Maintenance manhours

```
XMHRS = EXP(4.312739-.052122*X+.157473*X**2.-.010245*X**3.)                TRF10900
```

$$XMHRS = e^{4.312739-0.052122X+0.157473X^2-0.010245X^3}$$ [hrs/yr]

(3) Total materials and supplies

```
TMSU = EXP(5.105946+.465100*X)                                             TRF11000
```

$$TMSU = e^{5.105946+0.465100X}$$ [dollars/yr]

c. Total operating and maintenance costs

```
COSTO(N,1) = ((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.        TRF11500
```

$$COSTO = \frac{[(OHRS+XMHRS)*DHR*(1+PCT)]+(TMSU*WPI)}{Q_{Plant\ Inf.}*3650}$$ [cents/1000gal]

Final settler

a. Capital cost

Function of AFS

```
X = ALOG(AFS)                                                              TRF12100
```

$$X = \ln AFS$$

```
CCOST(N,2) = EXP(3.716354+.389861*X+.084560*X**2.-.004718*X**3.)*1000. TRF12200
```

$$CCOST = 1000e^{3.716354+0.389861X+0.084560X^2-0.004718X^3}$$ [dollars]

b. Operating manhours, maintenance manhours, and materials/supplies costs

Function of AFS/ECF

```
X = ALOG(AFS/DMATX(15,N))                                               TRF12900
```

$$X = \ln \frac{AFS}{ECF}$$

(1) Operating manhours

```
OHRS = EXP(5.846565+.254813*X+.113703*X**2.-.010942*X**3.)              TRF13500
```

$$OHRS = e^{5.846565+0.254813X+0.113703X^2-0.010942X^3}$$ [hrs/yr]

(2) Maintenance manhours

```
XMHRS = EXP(5.273419+.228329*X+.122646*X**2.-.011672*X**3.)             TRF13600
```

$$XMHRS = e^{5.273419+0.228329X+0.122646X^2-0.011672X^3}$$ [hrs/yr]

(3) Total materials and supplies

```
TMSU = EXP(5.669881+.750799*X)                                          TRF13700
```

$$TMSU = e^{5.669881+0.750799X}$$ [dollars/yr]

c. Total operating and maintenance costs

```
COSTO(N,2) = ((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.      TRF14200
```

$$COSTO = \frac{[(OHRS+XMHRS)*DHR*(1+PCT)]+(TMSU*WPI)}{Q_{Plant\ Inf.}*3650}$$ [cents/1000gal]

Waste sludge pumps

a. Capital cost

Function of Q_{IS1}*ECF

```
X = ALOG(SMATX(2,IS1)*1.5*DMATX(14,N))                                  TRF14800
```

$$X = \ln Q_{IS1}*1.5*ECF$$

`CCOST(N,3) = EXP(3.481553+.377485*X+.093349*X**2.-.006222*X**3.)*1000.` TRF14900

$$CCOST = 1000e^{3.481553+0.377485X+0.093349X^2-0.006222X^3} \quad \text{[dollars]}$$

b. Operating manhours, maintenance manhours, and materials/supplies costs

Function of Q_{IS1}

`X = ALOG(SMATX(2,IS1)*1.5)` TRF15700

$$X = \ln (Q_{IS1}*1.5)$$

(1) Operating manhours TRF16300

`OHRS = EXP(6.097269+.253066*X-.193659*X**2.+.078201*X**3.-.006680*X**4.)`

$$OHRS = e^{6.097269+0.253066X-0.193659X^2+0.078201X^3-0.006680X^4} \quad \text{[hrs/yr]}$$

(2) Maintenance manhours

`XMHRS = EXP(5.911541-.013158*X+.076643*X**2.)` TRF16500

$$XMHRS = e^{5.911541-0.013158X+0.076643X^2} \quad \text{[hrs/yr]}$$

(3) Kilowatt hrs per year

Pump efficiency - current values used in program; each can be changed by the replacement on punched card.

PEFF = 0.70 for $Q_{IS1}<1.44$MGD TRF16800

PEFF = 0.74 for $Q_{IS1}<10.08$MGD TRF17100

PEFF = 0.84 for $Q_{IS1}\geq 10.08$MGD TRF17300

`YRKW = SMATX(2,IS1)*1000000.*HEAD/1440./3960./PEFF/.9*.7457*24 *365.` TRF17400

$$YRKW = \frac{Q_{IS1}*1000000*HEAD*0.7457*24*365}{1440*3960*PEFF*0.9} \quad \text{[kilowatt/yrs]}$$

(4) Energy cost

`ECOST = YRKW*DMATX(10,20)` TRF17500

$$ECOST = YRKW*CKWH \quad \text{[dollars/yr]}$$

(5) Supplies

```
SCOST = EXP(5.851743+.301610*X+.197183*X**2.-.017962*X**3.)          TRF17600
```

$$SCOST = e^{5.851743+0.301610X+0.197183X^2-0.017962X^3} \qquad [\$/yr]$$

(6) Total materials and supplies

```
TMSU = ECOST+SCOST*WPI                                                TRF17700
```

$$TMSU = ECOST+(SCOST*WPI) \qquad [dollars/yr]$$

c. Total operating and maintenance costs

```
COSTO(N,3) = ((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU)/SMATX(2,1)/3650.        TRF18200
```

$$COSTO = \frac{[(OHRS+XMHRS)*DHR*(1+PCT)]+TMSU}{Q_{Plant\ Inf.}*3650} \qquad [cents/1000gal]$$

```
C
C         TRICKLING FILTER - FINAL SETTLER
C         PROCESS IDENTIFICATION NUMBER  11
C
      SUBROUTINE TRFS
C
C
C         COMMON INITIAL STATEMENTS
C
      INTEGER OS1,OS2
      COMMON SMATX(20,30),TMATX(20,30),DMATX(20,20),OMATX(20,20),IP(20),
     1INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),ACOST(20,5)
     2,TCOST(20,5),DHR,PCT,WPI,CLAND,DLAND,FLOW(25),POW(25),TKWHD(25)
C
C
C         PROCESS RELATIONSHIPS REQD. TO CALC. EFFLUENT STREAM
C         CHARACTERISTICS
C
      HEAD=DMATX(9,N)
      BODIN=SMATX(8,IS1)+SMATX(17,IS1)
      BETA=.0245*1.035**(DMATX(2,N)-20.)
      XN=.91-6.45/DMATX(4,N)
      QB=DMATX(7,N)*SMATX(2,IS1)
      RHQ=((DMATX(7,N)+1.)*DMATX(3,N))**XN
      BOD=(SMATX(17,IS1)+DMATX(6,N)*SMATX(8,IS1))/DMATX(1,N)
      DEPTH=RHQ*ALOG((BOD+DMATX(7,N))/(DMATX(7,N)+1.))/(BETA*DMATX(4,N))
      XPO=EXP(BETA*DMATX(4,N)*DEPTH/RHQ)
      BODO=BODIN/(XPO*(DMATX(7,N)*(1.-1./XPO)+1.))
      DBODO=SMATX(17,IS1)/(XPO*(DMATX(7,N)*(1.-1./XPO)+1.))
      SBOD4=BODO-DBODO
      SBOD5=SBOD4*DMATX(6,N)
      BETAN=.00307*1.141**(DMATX(2,N)-20.)
      XPON=EXP(BETAN*DMATX(4,N)*DEPTH/RHQ)
      SON4=SMATX(5,IS1)*SBOD4/SMATX(8,IS1)
      DN4=(SMATX(13,IS1)+SMATX(5,IS1)-SON4)/(XPON+(XPON-1.)*DMATX(7,N))
      DN5=DN4
      SON5=SON4*DMATX(6,N)
C
C
C         EFFLUENT STREAM CALCULATIONS
C
      SMATX(2,OS1)=SMATX(2,IS1)*(1.-DMATX(5,N))/(DMATX(6,N)-DMATX(5,N))
      SMATX(2,OS2)=SMATX(2,IS1)*(1.-DMATX(6,N))/(DMATX(5,N)-DMATX(6,N))
      SMATX(4,OS1)=SMATX(4,IS1)*DMATX(6,N)
      SMATX(4,OS2)=SMATX(4,IS1)*DMATX(5,N)
      SMATX(5,OS1)=SON5
      SMATX(5,OS2)=SON4*DMATX(5,N)
      SMATX(6,OS1)=SMATX(6,IS1)*DMATX(6,N)*SBOD4/SMATX(8,IS1)
      SMATX(6,OS2)=SMATX(6,IS1)*DMATX(5,N)*SBOD4/SMATX(8,IS1)
      SMATX(7,OS1)=SMATX(7,IS1)*DMATX(6,N)
      SMATX(7,OS2)=SMATX(7,IS1)*DMATX(5,N)
      SMATX(8,OS1)=SBOD4*DMATX(6,N)
      SMATX(8,OS2)=SBOD4*DMATX(5,N)
      SMATX(9,OS1)=SBOD4*DMATX(6,N)+SON5+SMATX(4,IS1)*DMATX(6,N)
      SMATX(9,OS2)=SBOD4*DMATX(5,N)+SON4*DMATX(5,N)+SMATX(4,IS1)*DMATX(5
     1,N)
      SMATX(10,OS1)=SMATX(9,OS1)+SMATX(7,OS1)+SMATX(6,OS1)
      SMATX(10,OS2)=SMATX(9,OS2)+SMATX(7,OS2)+SMATX(6,OS2)
      SMATX(12,OS1)=SMATX(12,IS1)                                       TRF05900
      SMATX(12,OS2)=SMATX(12,IS1)                                       TRF06000
      SMATX(13,OS1)=DN5                                                 TRF06100
      SMATX(13,OS2)=DN5                                                 TRF06200
      SMATX(14,OS1)=SMATX(14,IS1)+SMATX(6,IS1)*(1.-SBOD4/SMATX(8,IS1))  TRF06300
      SMATX(14,OS2)=SMATX(14,OS1)                                       TRF06400
      SMATX(15,OS1)=SMATX(15,IS1)                                       TRF06500
      SMATX(15,OS2)=SMATX(15,IS1)                                       TRF06600
      SMATX(16,OS1)=SMATX(16,IS1)                                       TRF06700
      SMATX(16,OS2)=SMATX(16,IS1)                                       TRF06800
      SMATX(17,OS1)=DBOD0                                               TRF06900
      SMATX(17,OS2)=SMATX(17,OS1)                                       TRF07000
      SMATX(3,OS1)=(SBOD5+1.87*SMATX(4,OS1))/1.87                       TRF07100
      SMATX(3,OS2)=(SMATX(8,OS2)+1.87*SMATX(4,OS2))/1.87                TRF07200
      SMATX(11,OS1)=(DBOD0+1.87*SMATX(12,OS1))/1.87                     TRF07300
      SMATX(11,OS2)=SMATX(11,OS1)                                       TRF07400
      SMATX(18,OS1)=SMATX(18,IS1)                                       TRF07500
      SMATX(18,OS2)=SMATX(18,IS1)                                       TRF07600
      SMATX(19,OS1)=SMATX(19,IS1)                                       TRF07700
      SMATX(19,OS2)=SMATX(19,IS1)                                       TRF07800
      SMATX(20,OS1)=SMATX(20,IS1)                                       TRF07900
      SMATX(20,OS2)=SMATX(20,IS1)                                       TRF08000
C                                                                       TRF08100
C                                                                       TRF08200
C             CALC. OF OUTPUT SIZES AND QUANTITIES                      TRF08300
C                                                                       TRF08400
      FAREA=SMATX(2,IS1)/DMATX(3,N)*43560.                              TRF08500
      PCR=(BODIN-DMATX(1,N))*100./BODIN                                 TRF08600
      AFS=SMATX(2,IS1)*1000./DMATX(8,N)*DMATX(15,N)                     TRF08700
      VOL=FAREA*DEPTH*DMATX(16,N)                                       TRF08800
C                                                                       TRF08900
C                                                                       TRF09000
C             CALC. OF CAPITAL COSTS FOR TRICKLING FILTER BASED ON      TRF09100
C             DESIGN PLUS EXCESS CAPACITY                               TRF09200
C                                                                       TRF09300
      X=ALOG(VOL/1000.)                                                 TRF09400
      CCOST(N,1)=EXP(2.924951+.036285*X+.114673*X**2.-.004587*X**3.)*100TRF09500
     10.                                                                TRF09600
C                                                                       TRF09700
C                                                                       TRF09800
C             CALC. OF OPERATING COSTS FOR TRICKLING FILTER BASED ON    TRF09900
C             DESIGN CAPACITY ALONE, DOES NOT INCLUDE EXCESS CAPACITY  TRF10000
C                                                                       TRF10100
      X=ALOG(SMATX(2,IS1)/DMATX(3,N)*43560./1000.)                      TRF10200
C                                                                       TRF10300
C                                                                       TRF10400
C                  CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS    TRF10500
C                  AND MATERIALS AND SUPPLIES                           TRF10600
C                                                                       TRF10700
      OHRS=EXP(4.536510-.095731*X+.173718*X**2.-.010114*X**3.)          TRF10800
      XMHRS=EXP(4.312739-.052122*X+.157473*X**2.-.010245*X**3.)         TRF10900
      TMSU=EXP(5.105946+.465100*X)                                      TRF11000
C                                                                       TRF11100
C                                                                       TRF11200
C                  OPERATING COST EQUATION                              TRF11300
C                                                                       TRF11400
      COSTO(N,1)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.  TRF11500
C                                                                       TRF11600
C                                                                       TRF11700
C             CALC. OF CAPITAL COSTS FOR FINAL SETTLER BASED ON DESIGN TRF11800
C             PLUS EXCESS CAPACITY                                      TRF11900
C                                                                       TRF12000
      X=ALOG(AFS)                                                       TRF12100
      CCOST(N,2)=EXP(3.716354+.389861*X+.084560*X**2.-.004718*X**3.)*100TRF12200
     10.                                                                TRF12300
C                                                                       TRF12400
```

```
C
C           CALC. OF OPERATING COSTS FOR FINAL SETTLER BASED ON
C           DESIGN CAPACITY ALONE, DOES NOT INCLUDE EXCESS CAPACITY
C
      X=ALOG(AFS/DMATX(15,N))
C
C
C                 CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS
C                 AND MATERIALS AND SUPPLIES
C
      OHRS=EXP(5.846565+.254813*X+.113703*X**2.-.010942*X**3.)
      XMHRS=EXP(5.273419+.228329*X+.122646*X**2.-.011672*X**3.)
      TMSU=EXP(5.669881+.750799*X)
C
C
C                 OPERATING COST EQUATION
C
      COSTO(N,2)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.
C
C
C           CALC. OF CAPITAL COSTS FOR SLUDGE RETURN PUMPS BASED
C           ON DESIGN PLUS EXCESS CAPACITY
C
      X=ALOG(SMATX(2,IS1)*1.5*DMATX(14,N))
      CCOST(N,3)=EXP(3.481553+.377485*X+.093349*X**2.-.006222*X**3.)*100
     10.
C
C
C           CALC. OF OPERATING COSTS FOR SLUDGE RETURN PUMPS BASED
C           ON DESIGN CAPACITY ALONE, DOES NOT INCLUDE EXCESS
C           CAPACITY
C
      X=ALOG(SMATX(2,IS1)*1.5)
C
C
C                 CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS
C                 AND MATERIALS AND SUPPLIES
C
      OHRS=EXP(6.097269+.253066*X-.193659*X**2.+.076201*X**3.-.006680*X*
     1*4.)
      XMHRS=EXP(5.911541-.013158*X+.076643*X**2.)
      X=ALOG(SMATX(2,IS1))
      IF (SMATX(2,IS1)-1.44) 10,20,20
   10 PEFF=.70
      GO TO 50
   20 IF (SMATX(2,IS1)-10.06) 30,40,40
   30 PEFF=.74
      GO TO 50
   40 PEFF=.83
   50 YRKW=SMATX(2,IS1)*1000000.*HEAD/1440./3960./PEFF/.9*.7457*24.*365.
      ECOST=YRKW*DMATX(10,20)
      SCOST=EXP(5.851743+.301610*X+.197183*X**2.-.017962*X**3.)
      TMSU=ECOST+SCOST*WPI
C
C
C                 OPERATING COST EQUATION
C
      COSTO(N,3)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU)/SMATX(2,1)/3650.
C
C
C           ASSIGNMENT OF VALUES TO OMATX
C
      OMATX(1,N)=AFS
      OMATX(2,N)=VOL
      OMATX(3,N)=FAREA
      OMATX(4,N)=DEPTH
```

```
C                                                               TRF19100
C                                                               TRF19200
C           PROCESS ENERGY INDICES                              TRF19300
C                                                               TRF19400
      FLOW(N)=SMATX(2,IS1)                                      TRF19500
      POW(N)=11.                                                TRF19600
      RETURN                                                    TRF19700
      END                                                       TRF19800
```

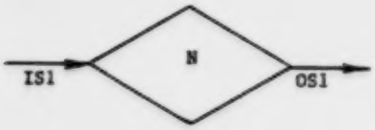
SECTION 13

CHLORINATION - DECHLORINATION, CHLOR

Subroutine Identification Number 12

Chlorination - Dechlorination, CHLOR   Rev. Date 8/1/77

1. Process symbol.



IS1: Liquid input stream

OS1: Liquid output stream

N: User assigned number to the process

2. Input parameters and nominal values.

DMATX(1,N) = DCL2	Dose of chlorine, mg/1. [8.]
DMATX(2,N) = TCL2	Chlorine contact time, minutes. [30.]
DMATX(3,N) = CCL2	Cost of chlorine, $/ton. [220.]
DMATX(4,N) = DSO2	Dose of sulfur dioxide, mg/1. [2.5]
DMATX(5,N) = CSO2	Cost of sulfur dioxide, $/ton. [180.]
DMATX(14,N) = ECF	Excess capacity factor for the sulfur dioxide feed system. [1.2]
DMATX(15,N) = ECF	Excess capacity factor for the chlorine feed system. [1.2]
DMATX(16,N) = ECF	Excess capacity factor for the contact basin. [1.5]

3. Output parameters which are printed on computer output sheets.

DCL2 = DMATX(1,N)

TCL2 = DMATX(2,N)

CCL2 = DMATX(3,N)

DSO2 = DMATX(4,N)

CSO2 = DMATX(5,N)

BVOL = OMATX(1,N)	Volume of the chlorine contact basin, [cu. ft.].

CUSE = OMATX(2,N)	Amount of chlorine used, [tons/yr].
SUSE = OMATX(3,N)	Amount of sulfur dioxide used, [tons/yr].
CCOST	Capital cost, [dollars].
COSTO	Operating and maintenance cost, [cents/1000 gal].
ACOST	Amortization cost, [cents/1000 gal].
TCOST	Total treatment cost, [cents/1000 gal].
ECF	Excess capacity factor.

4. Theory and functions - FORTRAN statement followed by equivalent algebraic equation.

```
BVOL = SMATX(2,IS1)*TCL2/1.44/7.48*1000.*DMATX(16,N)            CHL03300
```

$$BVOL = \frac{Q_{IS1}*TCL2*1000*ECF}{1.44*7.48} \qquad [ft^3]$$

```
CUSE = SMATX(2,IS1)*DCL2*8.33*365./2000.                         CHL03400
```

$$CUSE = \frac{Q_{IS1}*DCL2*8.33*365}{2000} \qquad [tons/yr]$$

```
SUSE = SMATX(2,IS1)*DSO2*8.33*365./2000.                         CHL03500
```

$$SUSE = \frac{Q_{IS1}*DSO2*8.33*365}{2000} \qquad [tons/yr]$$

```
FACTR = CUSE/(CUSE+SUSE)                                         CHL03600
```

$$FACTR = \frac{CUSE}{CUSE+SUSE} \qquad [no\ units]$$

```
OC = FACTR*OHRS                                                  CHL07800
```

$$OC = FACTR*OHRS$$

```
XC = FACTR*XMHRS                                                 CHL07900
```

$$XC = FACTR*XMHRS$$

References:

Smith, 1969

Patterson and Banker, 1971

5. **Cost functions.**

a. **Capital cost**

Contact basin:

Function of BVOL

```
X = ALOG(BVOL/1000.)                                         CHL04200
```

$$X = \ln \frac{BVOL}{1000}$$

```
CCOST(N,1) = EXP(2.048061+.521909*X-.002674*X**2.+.004159*X**3.)*1000.
                                                             CHL04300
```

$$CCOST = 1000e^{2.048061+0.521909X-0.002674X^2+0.004159X^3} \quad \text{[dollars]}$$

Cl_2 **feed system:**

```
CUSE = SMATX(2,IS1)*DCL2*8.33*365./2000.                     CHL03400
```

$$CUSE = \frac{Q_{IS1}*DCL2*8.33*365}{2000} \quad \text{[tons/yr]}$$

```
SUSE = SMATX(2,IS1)*DSO2*8.33*365./2000.                     CHL03500
```

$$SUSE = \frac{Q_{IS1}*DSO2*8.33*365}{2000} \quad \text{[tons/yr]}$$

```
FACTR = CUSE/(CUSE+SUSE)                                     CHL03600
```

$$FACTR = \frac{CUSE}{CUSE+SUSE} \quad \text{[no units]}$$

Function of CUSE

```
X = ALOG(CUSE*2000./365.*DMATX(15,N)+SUSE*2000./365.*DMATX(14,N))
```

$$X = \ln((CUSE*ECF_c+SUSE*ECF_s)*\frac{2000}{365}) \quad \text{CHL05500}$$

```
XCOST = EXP(2.264294-.044271*X+.065029*X**2.-.002536*X**3.)*1000.
                                                             CHL05600
```

$$XCOST = 1000e^{2.264294-0.044271X+0.065029X^2-0.002536X^3} \quad \text{[dollars]}$$

```
CCOST(N,2) = FACTR*XCOST                                     CHL06100
```

$$CCOST = \frac{CUSE}{CUSE+SUSE}*XCOST \quad \text{[dollars]}$$

SO_2 **Feed system (If used)**

Function of SUSE

```
CCOST(N,3) = XCOST-CCOST(N,2)          [dollars]             CHL10500
```

$$CCOST_s = XCOST-CCOST_c$$

b. Operating manhours, maintenance manhours and materials/supplies costs

Function of (CUSE+SUSE)

`X = ALOG(CUSE+SUSE)` CHL06900

$X = \ln\ (CUSE+SUSE)$

(1) Operating manhours (Cl_2+SO_2 Feed Systems)

`OHRS = EXP(4.538517+.543669*X)` CHL07000

$OHRS = e^{4.538517+0.543669X}$ [hrs/yr]

(2) Maintenance manhours (Cl_2+SO_2 Feed Systems)

`XMHRS = EXP(3.752071-.224812*X+.158849*X**2.-.006064*X**3.)` CHL07100

$XMHRS = e^{3.752071-0.224812X+0.158849X^2-0.006064X^3}$ [hrs/yr]

(3) Total materials and supplies (Cl_2+SO_2 Feed Systems)

`TMSU = EXP(6.126105+.287016*X)` CHL07200

$TMSU = e^{6.126105+0.287016X}$ [dollars/yr]

c. Total operating and maintenance costs

Contact Basin:

Operating cost assumed zero

`COSTO(N,1) = 0` CHL04900

COSTO = 0 [cents/1000 gal]

Cl_2 Feed System

(1) Operating manhours

`OC = FACTR*OHRS` CHL07800

(2) Maintenance manhours

`XC = FACTR*XMHRS` CHL07900

(3) Total materials and supplies

`TMSUC = CUSE*CCL2+FACTR*TMSU` CHL08000

TMSUC = (CUSE*CCL2)+(FACTR*TMSU) [dollars/yr]

COSTO(N,2) = ((OC+XC)*DHR*(1.+PCT)+TMSUC)/SMATX(2,1)/3650. CHL08500

$$\text{COSTO} = \frac{[(\text{OC}+\text{XC})*\text{DHR}*(1+\text{PCT})]+\text{TMSUC}}{Q_{\text{Plant Inf.}}*3650} \qquad [\text{cents/1000 gal}]$$

SO_2 Feed System (If Used)

(1) Operating manhours

OS = OHRS-OC CHL11200

(2) Maintenance manhours

XS = XMHRS-XC CHL11300

(3) Total materials and supplies

TMSUS = SUSE*CSO2+(1.-FACTR)*TMSU CHL11400

TMSUS = (SUSE*CSO2)+[(1-FACTR)*TMSU] [dollars/yr]

COSTO(N,3) = ((OS+XS)*DHR*(1.+PCT)+TMSUS)/SMATX(2,1)/3650. CHL12000

$$\text{COSTO} = \frac{[(\text{OS}+\text{XS})*\text{DHR}*(1+\text{PCT})]+\text{TMSUS}}{Q_{\text{Plant Inf.}}*3650} \qquad [\text{cents/1000 gal}]$$

```
C
C         CHLORINATION - DECHLORINATION
C         PROCESS IDENTIFICATION NUMBER  12
C
      SUBROUTINE CHLOR
C
C
C         COMMON INITIAL STATEMENTS
C
      INTEGER OS1,OS2
      COMMON SMATX(20,30),TMATX(20,30),DMATX(20,20),OMATX(20,20),IP(20),
     1INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),ACOST(20,5)
     2,TCOST(20,5),DHR,PCT,WPI,CLAND,DLAND,FLOW(25),POW(25),TKWHD(25)
C
C
C         ASSIGNMENT OF DESIGN VALUES TO PROCESS PARAMETERS
C
      DCL2=DMATX(1,N)
      TCL2=DMATX(2,N)
      CCL2=DMATX(3,N)
      DSO2=DMATX(4,N)
      CSO2=DMATX(5,N)
C
C
C         EFFLUENT STREAM CALCULATIONS
C
      DO 10 I=2,20
   10 SMATX(I,OS1)=SMATX(I,IS1)
C
C
C         CALC. OF OUTPUT SIZES AND QUANTITIES
C
      BVOL=SMATX(2,IS1)*TCL2/1.44/7.48*1000.*DMATX(16,N)
      CUSE=SMATX(2,IS1)*DCL2*8.33*365./2000.
      SUSE=SMATX(2,IS1)*DSO2*8.33*365./2000.
      FACTR=CUSE/(CUSE+SUSE)
C
C
C         CALC. OF CAPITAL COSTS FOR CONTACT BASIN BASED ON DESIGN
C         PLUS EXCESS CAPACITY
C
      X=ALOG(BVOL/1000.)
      CCOST(N,1)=EXP(2.048061+.521909*X-.002674*X**2.+.004159*X**3.)*100
     10.
C
C
C         CALC. OF OPERATING COSTS FOR CONTACT BASIN
C
      COSTO(N,1)=0.
C
C
C         CALC. OF CAPITAL COSTS FOR CHLORINE AND SULFUR DIOXIDE
C         FEED SYSTEMS BASED ON DESIGN PLUS EXCESS CAPACITY
C
      X=ALOG(CUSE*2000./365.*DMATX(15,N)+SUSE*2000./365.*DMATX(14,N))
      XCOST=EXP(2.264294-.044271*X+.065029*X**2.-.002536*X**3.)*1000.
C
C
```

```
C                CALC. OF CAPITAL COSTS FOR CHLORINE FEED SYSTEM
C
      CCOST(N,2)=FACTR*XCOST
C
C
C           CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS AND
C           MATERIALS AND SUPPLIES FOR CHLORINE AND SULFUR DIOXIDE
C           FEED SYSTEMS BASED ON DESIGN CAPACITY ALONE, DOES NOT
C           INCLUDE EXCESS CAPACITY
C
      X=ALOG(CUSE+SUSE)
      OHRS=EXP(4.538517+.543669*X)
      XMHRS=EXP(3.752071-.224812*X+.158849*X**2.-.006064*X**3.)
      TMSU=EXP(6.126105+.287016*X)
C
C
C                CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS
C                AND MATERIALS AND SUPPLIES FOR CHLORINE FEED SYSTEM
C
      OC=FACTR*OHRS
      XC=FACTR*XMHRS
      TMSUC=CUSE*CCL2+FACTR*TMSU
C
C
C                OPEARTING COST EQUATION FOR CHLORINE FEED SYSTEM
C
      COSTO(N,2)=((OC+XC)*DHR*(1.+PCT)+TMSUC)/SMATX(2,1)/3650.
C
C
C           CALC. OF CAPITAL AND OPERATING COSTS FOR SULFUR DIOXIDE
C           FEED SYSTEM
C
      IF (DSO2) 20,20,30
C
C
C                CALC. OF CAPITAL AND OPERATING COSTS FOR SULFUR
C                DIOXIDE FEED SYSTEM IF NO SO2 IS USED
C
   20 CCOST(N,3)=0.
      COSTO(N,3)=0.
      GO TO 40
C
C
C                CALC. OF CAPITAL COSTS FOR SULFUR DIOXIDE FEED
C                SYSTEM IF ANY SO2 IS USED
C
   30 CCOST(N,3)=XCOST-CCOST(N,2)
C
C
C                CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS
C                AND MATERIALS AND SUPPLIES FOR SULFUR DIOXIDE FEED
C                SYSTEM
C
      OS=OHRS-OC
      XS=XMHRS-XC
      TMSUS=SUSE*CSO2+(1.-FACTR)*TMSU
C
C
C                OPERATING COST EQUATION FOR SULFUR DIOXIDE FEED
C                SYSTEM
C
      COSTO(N,3)=((OS+XS)*DHR*(1.+PCT)+TMSUS)/SMATX(2,1)/3650.
C
C
C           ASSIGNMENT OF VALUES TO OMATX
```

```
C                                                                       CHL12400
   40 OMATX(1,N)=BVOL                                                   CHL12500
      OMATX(2,N)=CUSE                                                   CHL12600
      OMATX(3,N)=SUSE                                                   CHL12700
C                                                                       CHL12800
C                                                                       CHL12900
C             PROCESS ENERGY INDICES                                    CHL13000
C                                                                       CHL13100
      FLOW(N)=SMATX(2,IS1)                                              CHL13200
      POW(N)=12.                                                        CHL13300
      RETURN                                                            CHL13400
      END                                                               CHL13500
```

SECTION 14

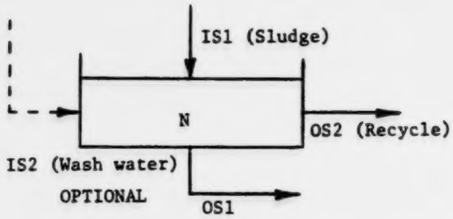
FLOTATION THICKENING, TFLOT

Subroutine Identification Number 13

Flotation Thickening, TFLOT

Rev. Date 8/1/77

1. Process symbol.



IS1: Sludge input stream

IS2: Wash water input stream

OS1: **Sludge** output stream

OS2: Recycle output stream

N: User assigned number to the process

2. Input parameters and nominal values.

DMATX(1,N) = TRR	Solids recovery ratio for thickening. [.95]
DMATX(2,N) = TSS	Total suspended solid concentration of OS1, mg/1. [40,000.]
DMATX(3,N) = GTH	Design overflow rate for the thickener, gpd/sq ft. [1150.]
DMATX(4,N) = GSTH	Design solids loading rate for the thickener, lb/day/sq ft. [48.]
DMATX(5,N) = HPWK	Hours per week that the thickener is operated, hr/wk. [100.]
DMATX(6,N) = DPOLY	Dose of polymer, lb/ton [10.]
DMATX(7,N) = CPOLY	Cost of polymer, $/ton. [.45]
DMATX(15,N) = ECF	Excess capacity factor for the process. [2.]

3. Output parameters which are printed on computer output sheets.

TRR = DMATX(1,N)

TSS = DMATX(2,N)

GTH = DMATX(3,N)

GSTH = DMATX(4,N)

HPWK = DMATX(5,N)

DPOLY = DMATX(6,N)

CPOLY = DMATX(7,N)	
ATHM = OMATX(1,N)	Surface area of each flotation thickener used, [sq ft.]
XN = OMATX(2,N)	Number of flotation thickeners used.
ATHM1 = OMATX(3,N)	Total required surface area for flotation thickening, [sq ft].
CCOST	Capital cost,[dollars].
COSTO	Operating and maintenance cost,[cents/ 1000gal].
ACOST	Amortization cost, [cents/1000 gal].
TCOST	Total treatment cost, [cents/1000 gal].
ECF	Excess capacity factor.

4. Theory and functions - FORTRAN statement followed by equivalent algebraic equation.

```
SMAT(I) = SMATX(I, IS2)                                        TFL02500
```

$$SMAT(I) = SMATX(I,IS2) \qquad [mg/1]$$

where I = 1,20 i.e. I,Q,SOC,SNBC,SON,SOP,SFM,SBOD,VSS,TSS,DOC,DNBC,DN,DP,DFM,
ALK,DBOD,NH3,NO3

```
SMATX(10,OS1) = DMATX(2,N)                                     TFL02600
```

$$TSS_{OS1} = TSS \qquad [mg/1]$$

```
SMATX(2,OS1) = DMATX(1,N)*(SMATX(2,IS1)*SMATX(10,IS1)+SMAT(2)*SMAT(10))/SMATX(10,OS1)
```

$$Q_{OS1} = \frac{TRR* [[Q_{IS1}*TSS_{IS1}]+[Q_{IS2}*TSS_{IS2}]]}{TSS_{OS1}} \qquad [MGD] \qquad TFL02700$$

```
ATH1 = (SMATX(2,IS1)*SMATX(10,IS1)+SMAT(2)*SMAT(10))*8.33/DMATX(4,N)*168./DMATX(5,N)
```

$$ATH1 = \frac{[Q_{IS1}*TSS_{IS1}+Q_{IS2}*TSS_{IS2}]*8.33*168}{GSTH*HPWK} \qquad [ft^2] \qquad TFL02900$$

```
ARCY = .00288*ATH1                                             TFL03400
```

$$ARCY = 0.00288ATH1 \qquad [MGD]$$

```
SMATX(2,IS2) = ARCY                                            TFL03500
```

$$Q_{IS2} = ARCY \qquad [MGD]$$

```
SMATX(2,OS2) = SMATX(2,IS1)+SMAT(2)-SMATX(2,OS1)                    TFL03700
```

$$Q_{OS2} = Q_{IS1}+Q_{IS2}-Q_{OS1} \qquad [\mathrm{MGD}]$$

```
ATH2 = SMATX(2,OS2)*1000000./DMATX(3,N)*168./DMATX(5,N)             TFL03800
```

$$ATH2 = \frac{Q_{OS2}*1000000*168}{GTH*HPWK} \qquad [ft^2]$$

```
ATHM = ATH2*DMATX(16,N)                                             TFL04000
```

$$ATHM = ATH2*ECF \qquad [ft^2]$$

```
ATHM = ATH1*DMATX(16,N)                                             TFL04200
```

$$ATHM = ATH1*ECF \qquad [ft^2]$$

```
TEMP = SMATX(2,IS1)*SMATX(10,IS1)+SMAT(2)*SMAT(10)                  TFL04300
```

$$TEMP = [Q_{IS1}*TSS_{IS1}]+[Q_{IS2}*TSS_{IS2}] \qquad [\mathrm{MGD\ (mg/l)}]$$

```
SMATX(10,OS2) = (TEMP-SMATX(2,OS1)*SMATX(10,OS1))/SMATX(2,OS2)      TFL04400
```

$$TSS_{OS2} = \frac{TEMP-(Q_{OS1}*TSS_{OS1})}{Q_{OS2}} \qquad [\mathrm{MGD\ (mg/l)}]$$

```
TEMP = TEMP/(SMATX(2,IS1)+SMAT(2))                                  TFL04500
```

$$TEMP = \frac{TEMP}{Q_{IS1}+Q_{IS2}} \qquad [\mathrm{mg/l}]$$

```
TEMP1 = SMATX(10,OS1)/TEMP                                          TFL04600
```

$$TEMP1 = \frac{TSS_{OS1}}{TEMP} \qquad [\text{no units}]$$

```
TEMP2 = SMATX(10,OS2)/TEMP                                          TFL04700
```

$$TEMP2 = \frac{TSS_{OS2}}{TEMP} \qquad [\text{no units}]$$

TEMP3 = (SMATX(2,IS1)*SMATX(I,IS1)+SMAT(2)*SMAT(I))/(SMATX(2,IS1)+SMAT(2))

$$\mathrm{TEMP3} = \frac{Q_{IS1}*\mathrm{SMATX(I,IS1)}+Q_{IS2}*\mathrm{SMAT(I)}}{Q_{IS1}+Q_{IS2}} \qquad [\mathrm{mg/l}] \qquad \mathrm{TFL05300}$$

where I = 3,9   i.e. SOC,SNBC,SON,SOP,SFM,SBOD,VSS

SMATX(I,OS1) = TEMP1*TEMP3 TFL05500

SMATX(I,OS1) = TEMP1*TEMP3 [mg/l]

where I = 3,9

SMATX(I,OS2) = TEMP2*TEMP3 TFL05600

SMATX(I,OS2) = TEMP2*TEMP3 [mg/l]

where I = 3,9

SMATX(I,OS1) = (SMATX(I,IS1)*SMATX(2,IS1)+SMAT(I)*SMAT(2))/(SMATX(2,IS1)+SMAT(2))

$$\mathrm{SMATX(I,OS1)} = \frac{[\mathrm{SMATX(I,IS1)}*Q_{IS1}]+[\mathrm{SMAT(I)}*Q_{IS2}]}{Q_{IS1}+Q_{IS2}} \quad [\mathrm{mg/l}] \qquad \mathrm{TFL05800}$$

where I = 11,20   i.e. DOC,DNBC,DN,DP,DFM,ALK,DBOD,NH3,NO3

SMATX(I,OS2) = SMATX(I,OS1) TFL06000

SMATX(I,OS2) = SMATX(I,OS1) [mg/l]

where I = 11,20

References:

Smith and Eilers, 1975
McMichael, 1973
Patterson and Banker, 1971

5. Cost Functions.

a. Capital cost

Function of ATHM

X = ALOG(ATHM) TFL09600

$X = \ln \mathrm{ATHM}$

```
CCOST(N,1) = EXP(1.717538+.453735*X)*1000.*XN                    TFL09700
```

$$CCOST = 1000XN*e^{1.717538+0.453735X} \qquad [\text{dollars}]$$

b. Operating manhours, maintenance manhours, and materials/supplies costs

Function of ATHM*XN/ECF

```
X = ALOG(ATHM/DMATX(16,N)*XN)                                    TFL10300
```

$$X = \ln \frac{ATHM*XN}{ECF}$$

(1) Operating manhours

```
OHRS = EXP(4.992517-.325053*X+.084026*X**2.)                     TFL10900
```

$$OHRS = e^{4.992517-0.325053X+0.084026X^2} \qquad [\text{hrs/yr}]$$

(2) Maintenance manhours

```
XMHRS = EXP(4.832373-.336504*X+.083020*X**2.)                    TFL11000
```

$$XMHRS = e^{4.832373-0.336504X+0.083020X^2} \qquad [\text{hrs/yr}]$$

(3) Materials and supplies

```
HPD = EXP(-1.254959+.852347*X)                                   TFL11100
```

$$HPD = e^{-1.254959+0.852347X}$$

```
ELEC = HPD*4.54*(DMATX(5,N)/7.)                                  TFL11200
```

$$ELEC = \frac{HPD*4.54*HPWK}{7} \qquad [\text{dollars/yr}]$$

```
PWAS = (SMATX(2,IS1)*SMATX(10,IS1)+SMAT(2)*SMAT(10))*8.33       TFL11300
```

$$PWAS = [(Q_{IS1}*TSS_{IS1})+(Q_{IS2}*TSS_{IS2})]*8.33 \qquad [\text{lb/day}]$$

```
POLC = PWAS*365./2000.*DMATX(6,N)*DMATX(7,N)                TFL11400
```

$$\mathrm{POLC} = \frac{\mathrm{PWAS*365*DPOLY*CPOLY}}{2000} \qquad [\mathrm{dollars/yr}]$$

c. Total operating and maintenance costs

```
COSTO(N,1) = ((OHRS+XMHRS)*DHR*(1.+PCT)+ELEC+POLC)/SMATX(2,1)/3650.
                                                                TFL11900
```

$$\mathrm{COSTO} = \frac{[(\mathrm{OHRS+XMHRS})*\mathrm{DHR}*(1+\mathrm{PCT})]+\mathrm{ELEC+POLC}}{Q_{\mathrm{Plant\ inf.}}{}^{*3650}} \qquad [\mathrm{cents/1000gal}]$$

```
C                                                                       TFL00100
C               FLOTATION THICKENING                                    TFL00200
C               PROCESS IDENTIFICATION NUMBER  13                       TFL00300
C                                                                       TFL00400
      SUBROUTINE TFLOT                                                  TFL00500
C                                                                       TFL00600
C                                                                       TFL00700
C               COMMON INITIAL STATEMENTS                               TFL00800
C                                                                       TFL00900
      INTEGER OS1,OS2                                                   TFL01000
      DIMENSION Y(12),SMAT(20)                                          TFL01100
      COMMON SMATX(20,30),TMATX(20,30),DMATX(20,20),OMATX(20,20),IP(20),TFL01200
     1INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),ACOST(20,5)TFL01300
     2,TCOST(20,5),DHR,PCT,WPI,CLAND,DLAND,FLOW(25),POW(25),TKWHD(25)   TFL01400
      DATA Y/25.,50.,100.,150.,200.,250.,300.,400.,500.,600.,800.,1000./TFL01500
C                                                                       TFL01600
C                                                                       TFL01700
C               PROCESS RELATIONSHIPS REQD. TO CALC. EFFLUENT STREAM    TFL01800
C               CHARACTERISTICS                                         TFL01900
C                                                                       TFL02000
      DO 10 I=1,20                                                      TFL02100
   10 SMAT(I)=0.                                                        TFL02200
      IF (IS2) 40,40,20                                                 TFL02300
   20 DO 30 I=1,20                                                      TFL02400
   30 SMAT(I)=SMATX(I,IS2)                                              TFL02500
   40 SMATX(10,OS1)=DMATX(2,N)                                          TFL02600
      SMATX(2,OS1)=DMATX(1,N)*(SMATX(2,IS1)*SMATX(10,IS1)+SMAT(2)*SMAT(1TFL02700
     10))/SMATX(10,OS1)                                                 TFL02800
      ATH1=(SMATX(2,IS1)*SMATX(10,IS1)+SMAT(2)*SMAT(10))*8.33/DMATX(4,N)TFL02900
     1*168./DMATX(5,N)                                                  TFL03000
      IF (IS2) 60,50,60                                                 TFL03100
   50 ARCY=0.                                                           TFL03200
      GO TO 70                                                          TFL03300
   60 ARCY=.00268*ATH1                                                  TFL03400
      SMATX(2,IS2)=ARCY                                                 TFL03500
   70 SMAT(2)=ARCY                                                      TFL03600
      SMATX(2,OS2)=SMATX(2,IS1)+SMAT(2)-SMATX(2,OS1)                    TFL03700
      ATH2=SMATX(2,OS2)*1000000./DMATX(3,N)*168./DMATX(5,N)             TFL03800
      IF (ATH1-ATH2) 80,90,90                                           TFL03900
   80 ATHM=ATH2*DMATX(16,N)                                             TFL04000
      GO TO 100                                                         TFL04100
   90 ATHM=ATH1*DMATX(16,N)                                             TFL04200
  100 TEMP=SMATX(2,IS1)*SMATX(10,IS1)+SMAT(2)*SMAT(10)                  TFL04300
      SMATX(10,OS2)=(TEMP-SMATX(2,OS1)*SMATX(10,OS1))/SMATX(2,OS2)      TFL04400
      TEMP=TEMP/(SMATX(2,IS1)+SMAT(2))                                  TFL04500
      TEMP1=SMATX(10,OS1)/TEMP                                          TFL04600
      TEMP2=SMATX(10,OS2)/TEMP                                          TFL04700
C                                                                       TFL04800
C                                                                       TFL04900
C               EFFLUENT STREAM CALCULATIONS                            TFL05000
C                                                                       TFL05100
      DO 110 I=3,9                                                      TFL05200
      TEMP3=(SMATX(2,IS1)*SMATX(I,IS1)+SMAT(2)*SMAT(I))/(SMATX(2,IS1)+SMTFL05300
     1AT(2))                                                            TFL05400
      SMATX(I,OS1)=TEMP1*TEMP3                                          TFL05500
  110 SMATX(I,OS2)=TEMP2*TEMP3                                          TFL05600
      DO 120 I=11,20                                                    TFL05700
      SMATX(I,OS1)=(SMATX(I,IS1)*SMATX(2,IS1)+SMAT(I)*SMAT(2))/(SMATX(2,TFL05800
     1IS1)+SMAT(2))
  120 SMATX(I,OS2)=SMATX(I,OS1)
C
C
C              CALC. OF OUTPUT SIZES AND QUANTITIES
C
      ATHM1=ATHM
      XN=0.
      XX=0.
      K=0
      DO 160 I=1,12
      IF (ATHM-Y(I)) 130,130,140
  130 ATHM=Y(I)
      GO TO 170
  140 IF (I-12) 160,150,160
  150 ATHM=Y(12)
  160 CONTINUE
  170 IF (ATHM-25.) 180,180,190
  180 ATHM=25.
      XN=1.
      GO TO 240
  190 IF (ATHM1-1000.) 230,230,200
  200 XN=ATHM1/1000.
      K=XN
      XX=K
      IF ((XN-XX)*1000.-500.) 210,210,220
  210 XN=XX+.5
      GO TO 240
  220 XN=XX+1.
      GO TO 240
  230 ATHM=ATHM/2.
      XN=2.
C
C
C              CALC. OF CAPITAL COSTS BASED ON DESIGN PLUS EXCESS
C              CAPACITY
C
  240 X=ALOG(ATHM)
      CCOST(N,1)=EXP(1.717538+.453735*X)*1000.*XN
C
C
C              CALC. OF OPERATING COSTS BASED ON DESIGN CAPACITY ALONE,
C              DOES NOT INCLUDE EXCESS CAPACITY
C
      X=ALOG(ATHM/DMATX(16,N)*XN)
C
C
C                    CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS
C                    ELECTRIC POWER AND POLYMER COSTS
C
      OHRS=EXP(4.992517-.325053*X+.084026*X**2.)
      XMHRS=EXP(4.832373-.356504*X+.083020*X**2.)
      HPD=EXP(-1.254959+.852347*X)
      ELEC=HPD*4.54*(DMATX(5,N)/7.)
      PWAS=(SMATX(2,IS1)*SMATX(10,IS1)+SMAT(2)*SMAT(10))*8.33
      POLC=PWAS*365./2000.*DMATX(6,N)*DMATX(7,N)
C
C
C                    OPERATING COST EQUATION
C
      COSTO(N,1)=((OHRS+XMHRS)*DHR*(1.+PCT)+ELEC+POLC)/SMATX(2,1)/3650.
C
C
C              ASSIGNMENT OF VALUES TO OMATX
C
      OMATX(1,N)=ATHM
      OMATX(2,N)=XN                                                     TFL12500
      OMATX(3,N)=ATHM1                                                  TFL12600
C                                                                       TFL12700
C                                                                       TFL12800
C             PROCESS ENERGY INDICES                                    TFL12900
C                                                                       TFL13000
      FLOW(N)=SMATX(2,IS1)                                              TFL13100
      POW(N)=13.                                                        TFL13200
      RETURN                                                            TFL13300
      END                                                               TFL13400
```

SECTION 15

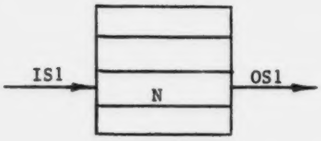
MULTIPLE HEARTH INCINERATION, MHINC

Subroutine Identification Number 14

Multiple Hearth Incineration, MHINC

Rev. Date 8/1/77

1. Process symbol.



IS1: Liquid input stream

OS1: Liquid output stream

N: User assigned number to the process

2. Input parameters and nominal values.

DMATX(1,N) = ML	Mass loading, lb/hr/sq ft of hearth area. [2.]
DMATX(2,N) = NINC	Number of multiple hearth incinerators. [1.]
DMATX(3,N) = HPWK	Hours per week that the incinerators are operated hr/wk. [35.]
DMATX(4,N) = SPER	Number of startup periods per week. [5.]
DMATX(5,N) = WV	Wind velocity, mph. [0.]
DMATX(6,N) = HV	Higher heat value for volatiles, Btu/lb. [10,000.]
DMATX(7,N) = TYPE	Program control: type of fuel used; 1 = fuel oil, 2 = natural gas, 3 = digester gas. [1.]
DMATX(8,N) = FC	Cost of fuel oil, $/gallon. [.30]
DMATX(9,N) = CNG	Cost of natural gas, $/1000 cu ft. [.97]
DMATX(16,N) = ECF	Excess capacity factor for the process. [1.]

3. Output parameters which are printed on computer output sheets.

OMATX(1,N) = FHA	Total hearth area, [sq ft].
OMATX(2,N) = WFYR	Total fuel usage, [lb/yr].
OMATX(3,N) = PSDD	Amount of dry solids to be incinerated, [lb/day].
OMATX(4,N) = ECOST	Cost of electrical power to operate the incinerator, [$/yr].
OMATX(5,N) = FCOST	Cost of fuel to operate the incinerator, [$/yr].

CCOST	Capital cost, [dollars].
COSTO	Operating and maintenance cost, [cents/1000 gal].
ACOST	Amortization cost, [cents/1000 gal].
TCOST	Total treatment cost, [cents/1000 gal].
ECF	Excess capacity factor.

4. Theory and functions - FORTRAN statement followed by equivalent algebraic equation.

`PSDD = SMATX(10,IS1)*SMATX(2,IS1)*8.33` MHI02500

$PSDD = 8.33TSS_{IS1}*Q_{IS1}$ [lb/day]

`FHAT = 58.31*SMATX(2,IS1)*SMATX(10,IS1)/DMATX(3,N)/DMATX(1,N)*DMATX(16,N)`

$FHAT = \frac{58.31\ Q_{IS1}*TSS_{IS1}*ECF}{HPWK*ML}$ MHI02600 $[ft^2]$

`XX = FHAT/DMATX(2,N)` MHI02800

$XX = \frac{FHAT}{NINC}$ $[ft^2]$

`FHA = SFHA(I)` MHI03100

FHA = SFHA(I) $[ft^2]$

where I = 1,59

`FHA = 3120` MHI03400 $[ft^2]$

`CYT = 13.+.024*FHA` (For FHA $\leq$ 1700) MHI03900

$CYT = 13+0.024FHA$ [hrs]

`CYT = .09*(FHA-1100.)` (For FHA $\leq$ 2300) MHI04200

$CYT = 0.09(FHA-1100)$ [hrs]

`PASH = (SMATX(10,IS1)-SMATX(9,IS1))/SMATX(9,IS1)` MHI04500

$PASH = \frac{TSS_{IS1}-VSS_{IS1}}{VSS_{IS1}}$ [no units]

`HASH = 68.*PASH` MHI04600

$HASH = 68PASH$ [BTU/lb dry VS]

`PWAT = (1000000.-SMATX(10,IS1))/SMATX(9,IS1)` MHI04700

$$PWAT = \frac{1000000-TSS_{IS1}}{VSS_{IS1}}$$ [no units]

`HWSL = 1404.3*PWAT` MHI04800

$$HWSL = 1404.3PWAT$$ [BTU/lb dry VS]

`SAREA = 64.03*FHA**.51` MHI04900

$$SAREA = 64.03[FHA]^{0.51}$$ [ft^2]

`VSPH = SMATX(9,IS1)*SMATX(2,IS1)*58.31/DMATX(3,N)` MHI05000

$$VSPH = \frac{VSS_{IS1}*Q_{IS1}*58.31}{HPWK}$$ [lb dry VS/hr]

`HC = 1.735*(1.+.374*DMATX(5,N))` MHI05100

$$HC = 1.735(1+0.374WV)$$ [BTU/hr/ft^2]

`QTRAN = (1.279+HC)*100.*SAREA*DMATX(2,N)/VSPH` MHI05200

$$QTRAN = \frac{100(1.279+HC)*SAREA*NINC}{VSPH}$$ [BTU/lb dry VS]

`QCOOL = 267.*FHA*DMATX(2,N)/VSPH` MHI05300

$$QCOOL = \frac{267FHA*NINC}{VSPH}$$ [BTU/lb dry VS]

`QNET = 2725.+HASH+HWSL+QCOOL+QTRAN-DMATX(6,N)+246.` MHI05400

$$QNET = 2725+HASH+HWSL+QCOOL+QTRAN-HV+246$$ [BTU/lb dry VS]

`TEMP = SMATX(9,IS1)*SMATX(2,IS1)*8.33*365.` MHI05700

$$TEMP = VSS_{IS1}*Q_{IS1}*8.33*365$$ [lb dry VS/yr]

`QNET = QNET*TEMP` MHI05800

$$QNET = QNET*VSS_{IS1}*Q_{IS1}8.33*365$$ [BTU/yr]

`YSBH = 8.*CYT/9.+8736.-52.*DMATX(3,N)*7./9.` MHI05900

$$YSBH = \frac{8CYT}{9} + 8736 - \frac{52HPWK*7}{9}$$ [hr/yr]

`YHUH = 10.*CYT/9.+52.*CYT*DMATX(4,N)/9.` MHI06000

$$YHUH = \frac{10CYT+(52CYT*SPER)}{9}$$ [hr/yr]

QHUP = YHUH*1913.*FHA*DMATX(2,N) MHI06100

$$\mathrm{QHUP} = \mathrm{YHUH}*1913\mathrm{FHA}*\mathrm{NINC} \qquad [\mathrm{BTU/yr}]$$

QSB = YSBH*315*FHA*DMATX(2,N) MHI06200

$$\mathrm{QSB} = 315\mathrm{YSBH}*\mathrm{FHA}*\mathrm{NINC} \qquad [\mathrm{BTU/yr}]$$

QTOT = QHUP+QSB+QNET MHI06300

$$\mathrm{QTOT} = \mathrm{QHUP}+\mathrm{QSB}+\mathrm{QNET} \qquad [\mathrm{BTU/yr}]$$

WFYR = QTOT/15019. (For oil) MHI06900

$$\mathrm{WFYR} = \frac{\mathrm{QHUP}+\mathrm{QSB}+\mathrm{QNET}}{15019} \qquad [\mathrm{lb/yr}]$$

FCOST = WFYR/7.481*DMATX(8,N) MHI07000

$$\mathrm{FCOST} = \frac{\mathrm{WFYR}*\mathrm{FC}}{7.481} \qquad [\mathrm{dollars/yr}]$$

WFYR = QTOT/15581. (For nat. gas) MHI07700

$$\mathrm{WFYR} = \frac{\mathrm{QTOT}}{15581} \qquad [\mathrm{lb/yr}]$$

FCOST = WFYR/45.8*DMATX(9,N) MHI07800

$$\mathrm{FCOST} = \frac{\mathrm{QTOT}*\mathrm{CNG}}{15581*45.8} \qquad [\mathrm{dollars/yr}]$$

CFDG = QTOT/8967./.0695 (For dig gas) MHI08500

$$\mathrm{CFDG} = \frac{\mathrm{QTOT}}{8967*0.0695} \qquad [\mathrm{ft}^3/\mathrm{yr}]$$

TYR = SMATX(10,IS1)*SMATX(2,IS1)*1.52 MHI09100

$$\mathrm{TYR} = \mathrm{TSS}_{\mathrm{IS1}}*\mathrm{Q}_{\mathrm{IS1}}*1.52$$

WTON = 554.24/FHA**.3572 MHI09200

$$\mathrm{WTON} = \frac{554.24}{[\mathrm{FHA}]^{0.3572}}$$

ECOST = WTON*TYR*DMATX(10,20) MHI09300

$$\mathrm{ECOST} = \mathrm{WTON}*\mathrm{TYR}*\mathrm{CKWH} \qquad [\mathrm{dollars/yr}]$$

DPTON = FCOST/(PSDD*365./2000.) MHI09900

$$\mathrm{DPTON} = \frac{\mathrm{FCOST}}{\frac{365\mathrm{PSDD}}{2000}} \qquad [\mathrm{dollars/ton}]$$

References:

Patterson and Banker, 1971

Smith and Eilers, 1975

5. Cost functions.

a. Capital cost

Function of PSDD*ECF

```
X = ALOG(PSDD/24.*DMATX(16,N))                                    MHI10500
```

$$X = \ln \frac{PSDD*ECF}{24}$$

```
CCOST(N,1) = EXP(2.377364+.598986*X)*1000.                        MHI10600
```

$$CCOST = 1000e^{2.377364+0.598986X} \qquad [\text{dollars}]$$

b. Operating manhours, maintenance manhours and materials/supplies costs

Function of $PSDD*\frac{VSS_{IS1}}{TSS_{IS1}}$

```
X = ALOG(PSDD*365./2000.*(SMATX(9,IS1)/SMATX(10,IS1)))            MHI11200
```

$$X = \ln \frac{365PSDD*VSS_{IS1}}{2000TSS_{IS1}}$$

(1) Operating manhours

```
OHRS = EXP(3.402537+1.215130*X-.157203*X**2.+.009771*X**3.)       MHI11800
```

$$OHRS = e^{3.402537+1.215130X-0.157203X^2+0.009771X^3} \qquad [\text{hrs/yr}]$$

(2) Maintenance manhours

```
XMHRS = EXP(3.906553+.702471*X-.088337*X**2.+.006827*X**3.)       MHI11900
```

$$XMHRS = e^{3.906553+0.702471X-0.088337X^2+0.006827X^3} \qquad [\text{hrs/yr}]$$

(3) Total materials and supplies

```
TMSU = EXP(7.864729-.338816*X+.054026*X**2.)                      MHI12000
```

$$TMSU = e^{7.864729-0.338816X+0.054026X^2} \qquad [\text{dollars/yr}]$$

c. **Total operating and maintenance costs** MHI12500

```
COSTO(N,1) = ((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI+ECOST+FCOST)/SMATX(2,1)/3650.
```

$$\text{COSTO} = \frac{(\text{OHRS+XMHRS})*\text{DHR}*(1+\text{PCT})+(\text{TMSU}*\text{WPI})+\text{ECOST}+\text{FCOST}}{Q_{\text{Plant Inf.}} * 3650} \quad [\text{cents/1000 gal}]$$

```
C
C           MULTIPLE HEARTH INCINERATION
C           PROCESS IDENTIFICATION NUMBER  14
C
      SUBROUTINE MHINC
C
C
C           COMMON INITIAL STATEMENTS
C
      INTEGER OS1,OS2
      DIMENSION SFHA(59)
      COMMON SMATX(20,30),TMATX(20,30),DMATX(20,20),OMATX(20,20),IP(20),
     1INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),ACOST(20,5)
     2,TCOST(20,5),DHR,PCT,WPI,CLAND,DLAND,FLOW(25),POW(25),TKWHD(25)
      DATA SFHA/85.,98.,112.,125.,126.,140.,145.,166.,187.,193.,208.,225
     1.,256.,276.,268.,319.,323.,351.,364.,383.,411.,452.,510.,560.,575.
     2,672.,760.,645.,857.,944.,988.,1041.,1066.,1117.,1128.,1249.,1260.
     3,1268.,1400.,1410.,1483.,1540.,1580.,1591.,1660.,1675.,1752.,1849.
     4,1875.,1933.,2060.,2084.,2090.,2275.,2350.,2464.,2600.,2860.,3120.
     5/
C
C
C           CALC. OF OUTPUT SIZES AND QUANTITIES
C
      PSDD=SMATX(10,IS1)*SMATX(2,IS1)*8.33
      FHAT=58.31*SMATX(2,IS1)*SMATX(10,IS1)/DMATX(3,N)/DMATX(1,N)*DMATX(
     116,N)
      XX=FHAT/DMATX(2,N)
      DO 20 I=1,59
      IF (XX-SFHA(I)) 10,10,20
   10 FHA=SFHA(I)
      GO TO 30
   20 CONTINUE
      FHA=3120.
   30 IF (FHA-200.) 40,40,50
   40 CYT=18.
      GO TO 100
   50 IF (FHA-1700.) 60,60,70
   60 CYT=13.+.024*FHA
      GO TO 100
   70 IF (FHA-2300.) 80,80,90
   80 CYT=.09*(FHA-1100.)
      GO TO 100
   90 CYT=108.
  100 PASH=(SMATX(10,IS1)-SMATX(9,IS1))/SMATX(9,IS1)
      HASH=68.*PASH
      PWAT=(1000000.-SMATX(10,IS1))/SMATX(9,IS1)
      HWSL=1404.3*PWAT
      SAERA=64.03*FHA**.51
      VSPH=SMATX(9,IS1)*SMATX(2,IS1)*58.31/DMATX(3,N)
      HC=1.735*(1.+.374*DMATX(5,N))
      QTRAN=(1.279+HC)*100.*SAERA*DMATX(2,N)/VSPH
      QCOOL=267.*FHA*DMATX(2,N)/VSPH
      QNET=2725.+HASH+HWSL+QCOOL+QTRAN-DMATX(6,N)+246.
      IF (QNET) 110,110,120
  110 QNET=0.
  120 TEMP=SMATX(9,IS1)*SMATX(2,IS1)*8.33*365.
      QNET=QNET*TEMP
      YSBH=8.*CYT/9.+8736.-52.*DMATX(3,N)*7./9.
      YHUH=10.*CYT/9.+52.*CYT*DMATX(4,N)/9.
      QHUP=YHUH*1913.*FHA*DMATX(2,N)
      QSB=YSBH*315.*FHA*DMATX(2,N)
      QTOT=QHUP+QSB+QNET
C
C
C                 CALC. OF FUEL COSTS IF FUEL OIL IS USED
C
      IF (DMATX(7,N)-1.) 130,130,140
  130 WFYR=QTOT/15019.
      FCOST=WFYR/7.481*DMATX(8,N)
      GO TO 180
C
C
C                 CALC. OF FUEL COSTS IF NATURAL GAS IS USED
C
  140 IF (DMATX(7,N)-2.) 150,150,160
  150 WFYR=QTOT/15561.
      FCOST=WFYR/45.8*DMATX(9,N)
      GO TO 180
C
C
C                 CALC. OF FUEL COSTS IF DIGESTER GAS IS USED
C
  160 IF (DMATX(7,N)-3.) 170,170,180
  170 CFDG=QTOT/8967./.0695
      FCOST=0.
C
C
C                 CALC. OF ELECTRICAL POWER COSTS
C
  180 TYR=SMATX(10,IS1)*SMATX(2,IS1)*1.52
      WTON=554.24/FHA**.3572
      ECOST=WTON*TYR*DMATX(10,20)
C
C
C                 RATIO OF FUEL COST TO AMOUNT OF DRY SOLIDS TO BE
C                 INCINERATED
C
      DPTON=FCOST/(PSDD*365./2000.)
C
C
C           CALC. OF CAPITAL COSTS BASED ON DESIGN PLUS EXCESS
C           CAPACITY
C
      X=ALOG(PSDD/24.*DMATX(16,N))
      CCOST(N,1)=EXP(2.377364+.598986*X)*1000.
C
C
C           CALC. OF OPERATING COSTS BASED ON DESIGN CAPACITY ALONE,
C           DOES NOT INCLUDE EXCESS CAPACITY
C
      X=ALOG(PSDD*365./2000.*(SMATX(9,IS1)/SMATX(10,IS1)))
C
C
C                 CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS
C                 AND MATERIALS AND SUPPLIES
C
      OHRS=EXP(3.402537+1.215130*X-.157203*X**2.+.009771*X**3.)
      XMHRS=EXP(3.906553+.702471*X-.088337*X**2.+.006827*X**3.)
      TMSU=EXP(7.864729-.338816*X+.054026*X**2.)
C
C
C                 OPERATING COST EQUATION
C
```

```
      COSTO(N,1)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI+ECOST+FCOST)/SMATX(MHI12500
     12,1)/3650.                                                        MHI12600
C                                                                       MHI12700
C                                                                       MHI12800
C               ASSIGNMENT OF VALUES TO OMATX                           MHI12900
C                                                                       MHI13000
      OMATX(1,N)=FHA                                                    MHI13100
      OMATX(2,N)=WFYR                                                   MHI13200
      OMATX(3,N)=PSDD                                                   MHI13300
      OMATX(4,N)=ECOST                                                  MHI13400
      OMATX(5,N)=FCOST                                                  MHI13500
      OMATX(6,N)=CFDG                                                   MHI13600
C                                                                       MHI13700
C                                                                       MHI13800
C               PROCESS ENERGY INDICES                                  MHI13900
C                                                                       MHI14000
      FLOW(N)=SMATX(2,IS1)                                              MHI14100
      POW(N)=14.                                                        MHI14200
      RETURN                                                            MHI14300
      END                                                               MHI14400
```

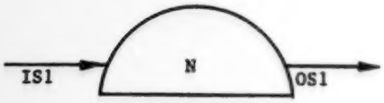
SECTION 16

RAW WASTEWATER PUMPING, RWP

Subroutine Identification Number 15

Raw Wastewater Pumping, RWP Rev. Date 8/1/77

1. Process symbol.



IS1: Liquid input stream
OS1: Liquid output stream
N: User assigned number to the process

2. Input parameters and nominal values.

DMATX(1,N) = HEAD	Pumping head of the influent pumps, ft. [30.]
DMATX(16,N) = ECF	Excess capacity factor for the pumps. [1.]

3. Output parameters which are printed on computer output sheets.

HEAD = DMATX(1,N)	
QP = OMATX(1,N)	Peak flow capacity of the raw wastewater pumping system, [MGD].
CCOST	Capital cost, [dollars].
COSTO	Operating and maintenance cost,[cents/1000gal].
ACOST	Amortization cost,[cents/1000gal].
TCOST	Total treatment cost,[cents/1000gal].
ECF	Excess capacity factor.

4. Theory and functions - FORTRAN statement followed by equivalent algebraic equation.

`SMATX(I,OS1) = SMATX(I,IS1)` RWP01900

SMATX(I,OS1) = SMATX (I,IS1) [mg/1]

`HEAD = DMATX(1,N)` RWP02400

HEAD = DMATX (1,N) [ft.]

`QP = 1.78*SMATX(2,IS1)**.92` $QP = 1.78[Q_{IS1}]^{0.92}$ [MGD] RWP02500

Pump Efficiency - Current values used in program; each can be changed by the replacement on punched card.

PEFF = 0.70 for $Q_{IS1}<1.44$ MGD RWP04900

PEFF = 0.74 for $Q_{IS1}<10.08$ MGD RWP05200

PEFF = 0.83 for $Q_{IS1} \geq 10.08$ MGD RWP05400

References:

Patterson and Banker, 1971

5. Cost functions.

a. Capital cost

Function of QP * ECF

`X = ALOG(QP*DMATX(16,N))` RWP03100

$X = \ln (QP * ECF)$

`CCOST(N,1) = EXP(4.004828+.519499*X+.082262*X**2.-.006492*X**3.)*1000.` RWP03200

$CCOST = 1000*e^{4.004828+.519499X+.082262X^2-.006492X^3}$ [dollars]

b. Operating manhours, maintenance manhours and materials/supplies costs

Function of Q_{IS1}

`X = ALOG(SMATX(2,IS1))` RWP03900

$X = \ln (Q_{IS1})$

(1) Operating manhours

```
OHRS = EXP(6.097269+.253066*X-.193659*X**2.+.078201*X**3.-.006680*X**4.)
```

RWP04500

$$\text{OHRS} = e^{6.097269+0.253066X-0.193659X^2+0.078201X^3-0.006680X^4} \qquad [\text{hrs/yr}]$$

(2) Maintenance manhours

```
XMHRS = EXP(5.911541-.013158*X+.076643*X**2.)                RWP04700
```

$$\text{XMHRS} = e^{5.911541-0.013158X+0.076643X^2} \qquad [\text{hrs/yr}]$$

(3) Kilowatt hrs per year

```
YRKW = SMATX(2,IS1)*1000000.*HEAD/1440./3960./PEFF/.9*.7457*24.*365.
```

RWP05500

$$\text{YRKW} = \frac{Q_{\text{IS1}}\text{*1000000HEAD*.7457*24*365}}{\text{1440*3960*PEFF*0.9}} \qquad [\text{KwHr/yr}]$$

(4) Energy cost

```
ECOST = YRKW*DMATX(10,20)                                    RWP05600
```

ECOST = YRKW*CKWH [dollars/yr]

(5) Supplies cost

```
SCOST = EXP(5.851743+.301610*X+.197183*X**2.-.017962*X**3.)  RWP05700
```

$$\text{SCOST} = e^{5.851743+0.301610X+0.197183X^2-0.017962X^3} \qquad [\text{dollars/yr}]$$

(6) Total materials and supplies

```
TMSU = ECOST + SCOST * WPI                                   RWP05800
```

TMSU = ECOST + (SCOST * WPI) [$/yr]

c. Total operating and maintenance costs

```
COSTO(N,1) = ((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU)/SMATX(2,1)/3650.
```

RWP06300

$$\text{COSTO} = \frac{\text{(OHRS+XMHRS)*DHR*(1 +PCT)+TMSU}}{Q_{\text{Plant Inf.}}\text{*3650}} \qquad [\text{cents/1000gal}]$$

Cost curves, Patterson and Banker pages 34, 83, 84

```
C                                                                       RWP00100
C             RAW WASTEWATER PUMPING                                    RWP00200
C             PROCESS IDENTIFICATION NUMBER  15                         RWP00300
C                                                                       RWP00400
      SUBROUTINE RWP                                                    RWP00500
C                                                                       RWP00600
C                                                                       RWP00700
C             COMMON INITIAL STATEMENTS                                 RWP00800
C                                                                       RWP00900
      INTEGER OS1,OS2                                                   RWP01000
      COMMON SMATX(20,30),TMATX(20,30),DMATX(20,20),OMATX(20,20),IP(20),RWP01100
     1INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),ACOST(20,5)RWP01200
     2,TCOST(20,5),DHR,PCT,WPI,CLAND,DLAND,FLOW(25),POW(25),TKWHD(25)   RWP01300
C                                                                       RWP01400
C                                                                       RWP01500
C             EFFLUENT STREAM CALCULATIONS                              RWP01600
C                                                                       RWP01700
      DO 10 I=2,20                                                      RWP01800
   10 SMATX(I,OS1)=SMATX(I,IS1)                                         RWP01900
C                                                                       RWP02000
C                                                                       RWP02100
C             CALC. OF OUTPUT SIZES AND QUANTITIES                      RWP02200
C                                                                       RWP02300
      HEAD=DMATX(1,N)                                                   RWP02400
      QP=1.78*SMATX(2,IS1)**.92                                         RWP02500
C                                                                       RWP02600
C                                                                       RWP02700
C             CALC. OF CAPITAL COSTS BASED ON DESIGN PLUS EXCESS        RWP02800
C             CAPACITY                                                  RWP02900
C                                                                       RWP03000
      X=ALOG(QP*DMATX(16,N))                                            RWP03100
      CCOST(N,1)=EXP(4.004828+.519499*X+.082262*X**2.-.006492*X**3.)*100RWP03200
     10.                                                                RWP03300
C                                                                       RWP03400
C                                                                       RWP03500
C             CALC. OF OPERATING COSTS BASED ON DESIGN CAPACITY ALONE,  RWP03600
C             DOES NOT INCLUDE EXCESS CAPACITY                          RWP03700
C                                                                       RWP03800
      X=ALOG(SMATX(2,IS1))                                              RWP03900
C                                                                       RWP04000
C                                                                       RWP04100
C                    CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS  RWP04200
C                    AND MATERIALS AND SUPPLIES                         RWP04300
C                                                                       RWP04400
      OHRS=EXP(6.097269+.253066*X-.193659*X**2.+.078201*X**3.-.006680*X*RWP04500
     1*4.)                                                              RWP04600
      XMHRS=EXP(5.911541-.013158*X+.076643*X**2.)                       RWP04700
      IF (SMATX(2,IS1)-1.44) 20,30,30                                   RWP04800
   20 PEFF=.70                                                          RWP04900
      GO TO 60                                                          RWP05000
   30 IF (SMATX(2,IS1)-10.08) 40,50,50                                  RWP05100
   40 PEFF=.74                                                          RWP05200
      GO TO 60                                                          RWP05300
   50 PEFF=.83                                                          RWP05400
   60 YRKW=SMATX(2,IS1)*1000000.*HEAD/1440./3960./PEFF/.9*.7457*24.*365.RWP05500
      ECOST=YRKW*DMATX(10,20)                                           RWP05600
      SCOST=EXP(5.851743+.301610*X+.197183*X**2.-.017962*X**3.)         RWP05700
      TMSU=ECOST+SCOST*WPI                                              RWP05800
```

```
C
C
C                    OPERATING COST EQUATION
C
      COSTO(N,1)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU)/SMATX(2,1)/3650.
C
C
C              ASSIGNMENT OF VALUES TO OMATX
C
      OMATX(1,N)=QP
C
C
C              PROCESS ENERGY INDICES
C
      FLOW(N)=SMATX(2,IS1)
      POW(N)=15.
      RETURN
      END
```

SECTION 17

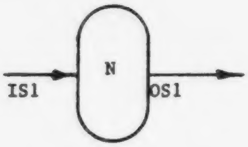
SLUDGE HOLDING TANKS, SHT

Subroutine Identification Number 16

Sludge Holding Tanks, SHT

Rev. Date 8/1/77

1. Process symbol.



IS1: Sludge input stream

OS1: Sludge output stream

N: User assigned number to the process

2. Input parameters and nominal values.

DMATX(1,N) = TD	Sludge holding tank detention time, days. [15.]
DMATX(16,N) = ECF	Excess capacity factor for the process. [1.]

3. Output parameters which are printed on computer output sheets.

TD = DMATX(1,N)	
VSHT = OMATX(1,N)	Volume of the sludge holding tanks, cu ft/ 1000.
CCOST	Capital cost, [dollars].
COSTO	Operating and maintenance cost, [cents/1000 gal].
ACOST	Amortization cost, [cents/1000 gal].
TCOST	Total treatment cost, [cents/1000 gal].
ECF	Excess capacity factor.

4. Theory and functions - FORTRAN statement followed by equivalent algebraic equation.

```
SMATX(I,OS1) = SMATX(I,IS1)                                   SHT01900
```

SMATX(I,OS1) = SMATX(I,IS1)   [mg/l]

where I = 2,20

i.e. Q, SOC, SNBC, SON, SOP, SFM, SBOD, VSS, TSS, DOC, DNBC, DN, DP, DFM, ALK, DBOD, NH3, NO3

`VSHT = SMATX(2,IS1)*DMATX(1,N)*1000./7.48*DMATX(16,N)` SHT02400

$$VSHT = \frac{Q_{IS1}*TD*ECF*1000}{7.48} \qquad [ft^3/1000]$$

`V1 = SMATX(2,IS1)*DMATX(1,N)*1000./7.48` SHT03800

$$V1 = \frac{Q_{IS1}*TD*1000}{7.48} \qquad [ft^3/1000]$$

References:

Smith and Eilers, 1975

Patterson and Banker, 1971

5. Cost functions.

a. Capital cost

Function of VSHT

`X = ALOG(VSHT)` SHT03000

$$X = \ln VSHT$$

`CCOST(N,1) = EXP(2.625751+.484180*X+.000613*X**2.+.002252*X**3.)*1000.` SHT03100

$$CCOST = 1000e^{2.625751+0.484180X+0.000613X^2+0.002252X^3} \qquad [dollars]$$

b. Operating manhours, maintenance manhours and materials/supplies costs

Function of V1

`X = ALOG(V1)` SHT03900

$$X = \ln (V1)$$

(1) Operating manhours

`OHRS = EXP(5.727345+.000762*X+.098701*X**2.-.006786*X**3.)` SHT04500

$$OHRS = e^{5.727345+0.000762X+0.098701X^2-0.006786X^3} \qquad [hrs/yr]$$

(2) Maintenance manhours

`XMHRS = EXP(4.506628+.214662*X+.071402*X**2.-.004681*X**3.)` SHT04600

$$XMHRS = e^{4.506628+0.214662X+0.071402X^2-0.004681X^3} \qquad [hrs/yr]$$

(3) Total materials and supplies

`TMSU = EXP(5.479939+.299282*X+.106008*X**2.-.008658*X**3.)` SHT04700

$$TMSU = e^{5.479939+0.299282X+0.106008X^2-0.008658X^3} \qquad [dollars/yr]$$

c. Total operating and maintenance costs SHT05200

```
COSTO(N,1) = ((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.
```

$$\text{COSTO} = \frac{[(\text{OHRS}+\text{XMHRS})*\text{DHR}*(1+\text{PCT})]+(\text{TMSU}*\text{WPI})}{Q_{\text{Plant Inf.}}*3650} \quad [\text{cents/1000 gal}]$$

Cost curves, Patterson and Banker pages 46,98,99

```
C
C          SLUDGE HOLDING TANKS
C          PROCESS IDENTIFICATION NUMBER  16
C
      SUBROUTINE SHT
C
C
C          COMMON INITIAL STATEMENTS
C
      INTEGER OS1,OS2
      COMMON SMATX(20,30),TMATX(20,30),DMATX(20,20),OMATX(20,20),IP(20),
     1INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),ACOST(20,5)
     2,TCOST(20,5),DHR,PCT,WPI,CLAND,DLAND,FLOW(25),POW(25),TKWHD(25)
C
C
C          EFFLUENT STREAM CALCULATIONS
C
      DO 10 I=2,20
   10 SMATX(I,OS1)=SMATX(I,IS1)
C
C
C          CALC. OF OUTPUT SIZES AND QUANTITIES
C
      VSHT=SMATX(2,IS1)*DMATX(1,N)*1000./7.48*DMATX(16,N)
C
C
C          CALC. OF CAPITAL COSTS BASED ON DESIGN PLUS EXCESS
C          CAPACITY
C
      X=ALOG(VSHT)
      CCOST(N,1)=EXP(2.625751+.484180*X+.000613*X**2.+.002252*X**3.)*100
     10.
C
C
C          CALC. OF OPERATING COSTS BASED ON DESIGN CAPACITY ALONE,
C          DOES NOT INCLUDE EXCESS CAPACITY
C
      V1=SMATX(2,IS1)*DMATX(1,N)*1000./7.48
      X=ALOG(V1)
C
C
C              CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS
C              AND MATERIALS AND SUPPLIES
C
      OHRS=EXP(5.727345+.000762*X+.098701*X**2.-.006786*X**3.)
      XMHRS=EXP(4.506628+.214662*X+.071402*X**2.-.004681*X**3.)
      TMSU=EXP(5.479939+.299282*X+.106008*X**2.-.006658*X**3.)
C
C
C              OPERATING COST EQUATION
C
      COSTO(N,1)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.
C
C
C          ASSIGNMENT OF VALUES TO OMATX
C
      OMATX(1,N)=VSHT
C
```

```
C                                                                       SHT05900
C               PROCESS ENERGY INDICES                                  SHT06000
C                                                                       SHT06100
      FLOW(N)=SMATX(2,IS1)                                              SHT06200
      POW(N)=16.                                                        SHT06300
      RETURN                                                            SHT06400
      END                                                               SHT06500
```

SECTION 18

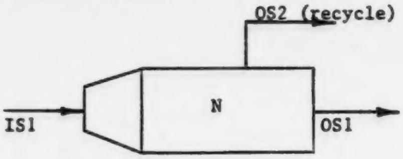
CENTRIFUGATION, CENT

Subroutine Identification Number 17

Centrifugation, CENT

Rev. Date 8/1/77

1. Process symbol.



IS1: Sludge input stream

OS1: Sludge cake output stream

OS2: Centrate output stream

N: User assigned number to the process.

2. Input parameters and nominal values.

DMATX(1,N) = CRR	Solids recovery ratio for centrifugation. [.95]
DMATX(2,N) = TSS	Total suspended solids concentration of OS1, mg/l. [200,000.]
DMATX(3,N) = HPWK	Hours per week that the centrifuges are operated, hr/wk. [35.]
DMATX(4,N) = XCEN	Program control: 0 = landfill sludge disposal, 1 = incineration sludge disposal. [0.]
DMATX(5,N) = POLY	Dose of polymer added to condition sludge, lb/ton. [2.]
DMATX(6,N) = CPOLY	Cost of polymer, $/lb. [2.]
DMATX(7,N) = GPMN	Capacity of each centrifuge that is used (4 sizes of centrifuges are possible depending on the type of sludge), gpm. [100.]
DMATX(8,N) = CNMIN	Minimum number of centrifuges to be used. [2.]
DMATX(16,N) = ECF	Excess capacity factor for the process. [1.]

3. Output parameters which are printed on computer output sheets.

HPWK = DMATX(3,N)

XCEN = DMATX(4,N)

POLY = DMATX(5,N)

CPOLY = DMATX(6,N)

GPMN = DMATX(7,N)

CNMIN = DMATX(8,N)	
CGPM = OMATX(1,N)	Design capacity of the centrifuges, [gpm.]
DSOL = OMATX(2,N)	Dry solids incl. chem fed to centrifuges, [tons/yr.]
AFC = OMATX(3,N)	Amortization factor for centrifuges based on a 10 year lifetime.
CSIZE = OMATX(4,N)	Size of each centrifuge used, [gpm.]
CN = OMATX(5,N)	Number of centrifuges used.
CCOST	Capital cost, [dollars]
COSTO	Operating and maintenance cost, [cents/1000 gal.]
ACOST	Amortization cost, [cents/1000 gal.]
TCOST	Total treatment cost, [cents/1000 gal.]
ECF	Excess capacity factor.

References:

Patterson and Banker, 1971

Smith and Eilers, 1975

4. Theory and functions - FORTRAN statement followed by an equivalent algebraic equation.

SMATX(7,IS1) = SMATX(7,IS1)+POLY*SMATX(10,IS1)/2000. CEN02900

$$SFM_{IS1} = SFM_{IS1} + \frac{POLY*TSS_{IS1}}{2000} \qquad [mg/l]$$

SMATX(10,IS1) = SMATX(10,IS1)+POLY*SMATX(10,IS1)/2000. CEN03000

$$TSS_{IS1} = TSS_{IS1} + \frac{POLY*TSS_{IS1}}{2000} \qquad [mg/l]$$

DSOL = SMATX(10,IS1)*SMATX(2,IS1)*8.33*365./2000. CEN03100

$$DSOL = \frac{TSS_{IS1}*Q_{IS1}*8.33*365}{2000} \qquad [ton/yr]$$

SMATX(10,OS2) = ((1.-DMATX(1,N))/(1.-DMATX(1,N)*SMATX(10,IS1)/DMATX(2,N)))*SMATX(10,IS1)

$$TSS_{OS2} = \frac{(1-CRR)*TSS_{IS1}}{1-\frac{CRR*TSS_{IS1}}{TSS_{OS1}}}$$

[mg/1] CEN03200

TEMP1 = DMATX(2,N)/SMATX(10,IS1) CEN03400

$$TEMP1 = \frac{TSS_{OS1}}{TSS_{IS1}}$$

TEMP2 = SMATX(10,OS2)/SMATX(10,IS1) CEN03500

$$TEMP2 = \frac{TSS_{OS2}}{TSS_{IS1}}$$

SMATX(10,OS1) = DMATX(2,N) CEN03600

$$TSS_{OS1} = TSS_{OS1}$$

[mg/1]

SMATX(2,OS1) = (SMATX(10,IS1)-SMATX(10,OS2))*SMATX(2,IS1)/(SAMTX(10,OS1)-SMATX(10,OS2))

$$Q_{OS1} = \frac{(TSS_{IS1}-TSS_{OS2})*Q_{IS1}}{(TSS_{OS1}-TSS_{OS2})}$$

[MGD] CEN03700

SMATX(2,OS2) = SMATX(2,IS1)-SMATX(2,OS1) CEN03900

$$Q_{OS2} = Q_{IS1}-Q_{OS1}$$

[MGD]

SMATX(I,OS1) = TEMP1*SMATX(I,IS1) CEN04500

SMATX(I,OS1) = TEMP1*SMATX(I,IS1) [mg/1]

where I = 3,9

i.e. SOC, SNBC,SON,SOP,SFM,SBOD,VSS

SMATX(I,OS2) = TEMP2*SMATX(I,IS1) CEN04600

SMATX(I,OS2) = TEMP2*SMATX(I,IS1) [mg/1]

where I = 3,9

SMATX(I,OS1) = SMATX(I,IS1) CEN04800

SMATX(I,OS1) = SMATX(I,IS1) [mg/1]

where I = 11,20

i.e. DOC,DNBC,DN,DP,DFM,ALK,DBOD,NH3,NO3

SMATX(I,OS2) = SMATX(I,IS1) CEN04900

SMATX(I,OS2) = SMATX(I,IS1) [mg/1]

where I = 11,20

`CN = CNMIN` CEN05400

$$CN = CNMIN$$

`CGPM = SMATX(2, IS1)*116666.7/HPWK*DMATX(16,N)/CN` CEN05500

$$CGPM = \frac{116666.7*Q_{IS1}*ECF}{HPWK*CN} \qquad [gpm/centrifuge]$$

`CSIZE = .275*GPMN` CEN05700

$$CSIZE = 0.275\ GPMN$$

`CSIZE = .350*GPMN` [For (CGPM-CSIZE)>0] CEN06400

$$CSIZE = 0.350\ GPMN$$

`CSIZE = .590*GPMN` [For (CGPM-CSIZE)>0] CEN06600

$$CSIZE = 0.590\ GPMN$$

`CSIZE = GPMN` [For (CGPM-CSIZE)>0] CEN06800

$$CSIZE = GPMN$$

`NCN = CGPM/CSIZE` CEN06900

$$NCN = \frac{CGPM}{CSIZE}$$

5. Cost functions. (Cost curves, Banker and Patterson page 109)

   a. Capital cost

      Function of GPMM, CSIZE and CN

`CCOST(N,1) = 78500.*(1.-.044*(CN-2.))*CN` CEN09000

$$CCOST = 78500CN*(1-0.044(CN-2)) \qquad [dollars]$$

`CCOST(N,1) = 98000.*(1.-.044*(CN-2.))*CN` CEN09800

$$CCOST = 98000CN*(1-0.044(CN-2)) \qquad [dollars]$$

`CCOST(N,1) = 140000.*(1.-.044*(CN-2.))*CN` CEN10600

$$CCOST = 140000CN*(1-0.044(CN-2)) \qquad [dollars]$$

`CCOST(N,1) = 160000.*(1.-.044*(CN-2.))*CN` CEN11400

$$CCOST = 160000CN*(1-0.044(CN-2)) \qquad [dollars]$$

Amortization factor for centrifuges

`AFC = DMATX(3,20)*(1.+DMATX(3,20))**10./((1.+DMATX(3,20))**10.-1.)`

$$AFC = \frac{RI[1+RI]^{10}}{[1+RI]^{10}-1}$$ CEN11900

Amortization cost

`ACOST(N,1) = CCOST(N,1)*AFC/SMATX(2,1)/3650.` CEN12000

$$ACOST = \frac{CCOST * AFC}{Q_{Plant\ Inf.} * 3650}$$ [cents/1000 gal]

b. Operating manhours, maintenance manhours and materials/supplies costs

Function of DSOL.

`X = ALOG (DSOL)` CEN12600

$X = \ln DSOL$

(1) Operating manhours

(For XCEN = 0)

`OHRS = EXP(7.621517-.476977*X+.071516*X**2.)` CEN13300

$$OHRS = e^{7.621517-0.476977X+0.071516X^2}$$ [hrs/yr]

(For XCEN ≠ 0)

`OHRS = EXP(7.264153-.466246*X+.069552*X**2.)` CEN14000

$$OHRS = e^{7.264153-0.466246X+0.069552X^2}$$ [hrs/yr]

(2) Maintenance manhours

`XMHRS = EXP(5.997115-.493809*X+.070892*X**2.)` CEN14600

$$XMHRS = e^{5.997115-0.493809X+0.070892X^2}$$ [hrs/yr]

(3) Total materials and supplies

`SUPP = EXP(-2.822519+.700948*X)*1000.` CEN14700

$$SUPP = 1000e^{-2.822519+0.700948X}$$ [dollars/yr]

`CHEM = DSOL*POLY*CPOLY` CEN14800

CHEM = DSOL*POLY*CPOLY [dollars/yr]

c. Total operating and maintenance costs

`COSTO(N,1) = ((OHRS+XMHRS)*DHR*(1.+PCT)+SUPP*WPI+CHEM)/SMATX(2,1)/3650.` CEN15300

$$COSTO = \frac{(OHRS+XMHRS)*DHR*(1+PCT)+(SUPP*WPI)+CHEM}{Q_{Plant\ Inf.} * 3650}$$ [cents/1000 gal]

```
C
C           CENTRIFUGATION
C           PROCESS IDENTIFICATION NUMBER  17
C
      SUBROUTINE CENT
C
C
C           COMMON INITIAL STATEMENTS
C
      INTEGER OS1,OS2
      COMMON SMATX(20,30),TMATX(20,30),DMATX(20,20),OMATX(20,20),IP(20),
     1INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),ACOST(20,5)
     2,TCOST(20,5),DHR,PCT,WPI,CLAND,DLAND,FLOW(25),POW(25),TKWHD(25)
C
C
C           ASSIGNMENT OF DESIGN VALUES TO PROCESS PARAMETERS
C
      HPWK=DMATX(3,N)
      XCEN=DMATX(4,N)
      POLY=DMATX(5,N)
      CPOLY=DMATX(6,N)
      GPMN=DMATX(7,N)
      CNMIN=DMATX(8,N)
C
C
C           PROCESS RELATIONSHIPS REQD. TO CALC. EFFLUENT STREAM
C           CHARACTERISTICS
C
      SMATX(7,IS1)=SMATX(7,IS1)+POLY*SMATX(10,IS1)/2000.
      SMATX(10,IS1)=SMATX(10,IS1)+POLY*SMATX(10,IS1)/2000.
      DSOL=SMATX(10,IS1)*SMATX(2,IS1)*8.33*365./2000.
      SMATX(10,OS2)=((1.-DMATX(1,N))/(1.-DMATX(1,N)*SMATX(10,IS1)/DMATX(
     12,N)))*SMATX(10,IS1)
      TEMP1=DMATX(2,N)/SMATX(10,IS1)
      TEMP2=SMATX(10,OS2)/SMATX(10,IS1)
      SMATX(10,OS1)=DMATX(2,N)
      SMATX(2,OS1)=(SMATX(10,IS1)-SMATX(10,OS2))*SMATX(2,IS1)/(SMATX(10,
     1OS1)-SMATX(10,OS2))
      SMATX(2,OS2)=SMATX(2,IS1)-SMATX(2,OS1)
C
C
C           EFFLUENT STREAM CALCULATIONS
C
      DO 10 I=3,9
      SMATX(I,OS1)=TEMP1*SMATX(I,IS1)
   10 SMATX(I,OS2)=TEMP2*SMATX(I,IS1)
      DO 20 I=11,20
      SMATX(I,OS1)=SMATX(I,IS1)
   20 SMATX(I,OS2)=SMATX(I,IS1)
C
C
C           CALC. OF OUTPUT SIZES AND QUANTITIES
C
      CN=CNMIN
      CGPM=SMATX(2,IS1)*116666.7/HPWK*DMATX(16,N)/CN
      GPMM=SMATX(2,IS1)*1000000./1440.
      CSIZE=.275*GPMN
C
```

```
C
C             CALC. OF CAPITAL COSTS BASED ON DESIGN PLUS EXCESS
C             CAPACITY
C
      IF (CGPM-CSIZE) 60,60,30
   30 CSIZE=.350*GPMN
      IF (CGPM-CSIZE) 80,80,40
   40 CSIZE=.590*GPMN
      IF (CGPM-CSIZE) 100,100,50
   50 CSIZE=GPMN
      NCN=CGPM/CSIZE
      CN=NCN+1
      GO TO 120
   60 IF (GPMM-CSIZE*(CN-1.)) 140,140,70
   70 CN=CN+1.
      GO TO 60
   80 IF (GPMM-CSIZE*(CN-1.)) 150,150,90
   90 CN=CN+1.
      GO TO 80
  100 IF (GPMM-CSIZE*(CN-1.)) 160,160,110
  110 CN=CN+1.
      GO TO 100
  120 IF (GPMM-CSIZE*(CN-1.)) 170,170,130
  130 CN=CN+1.
      GO TO 120
C
C
C                      CALC. OF CAPITAL COSTS FOR CENT FACILITY WHOSE
C                      DESIGN CAPACITY DOES NOT EXCEED 27.5% OF THE CAPACITY
C                      OF EACH CENTRIFUGE
C
  140 CCOST(N,1)=78500.*(1.-.044*(CN-2.))*CN
      GO TO 180
C
C
C                      CALC. OF CAPITAL COSTS FOR CENT FACILITY WHOSE
C                      DESIGN CAPACITY DOES NOT EXCEED 35% OF THE CAPACITY
C                      OF EACH CENTRIFUGE
C
  150 CCOST(N,1)=98000.*(1.-.044*(CN-2.))*CN
      GO TO 180
C
C
C                      CALC. OF CAPITAL COSTS FOR CENT FACILITY WHOSE
C                      DESIGN CAPACITY DOES NOT EXCEED 59% OF THE CAPACITY
C                      OF EACH CENTRIFUGE
C
  160 CCOST(N,1)=140000.*(1.-.044*(CN-2.))*CN
      GO TO 180
C
C
C                      CALC. OF CAPITAL COSTS FOR CENT FACILITY WHOSE
C                      DESIGN CAPACITY EQUALS THE CAPACITY OF EACH CENTRI-
C                      FUGE.
C
  170 CCOST(N,1)=160000.*(1.-.044*(CN-2.))*CN
C
C
C                CALC. OF AMORTIZATION COSTS
C
  180 AFC=DMATX(3,20)*(1.+DMATX(3,20))**10./((1.+DMATX(3,20))**10.-1.)
      ACOST(N,1)=CCOST(N,1)*AFC/SMATX(2,1)/3650.
C
C
C                CALC. OF OPERATING COSTS BASED ON DESIGN CAPACITY ALONE,
C                DOES NOT INCLUDE EXCESS CAPACITY
```

```
C                                                                       CEN12500
      X=ALOG(DSOL)                                                      CEN12600
      IF (XCEN) 200,190,200                                             CEN12700
C                                                                       CEN12800
C                                                                       CEN12900
C                  CALC. OF OPERATING MANHOURS IF LANDFILL DISPOSAL IS  CEN13000
C                  USED                                                 CEN13100
C                                                                       CEN13200
  190 OHRS=EXP(7.621517-.476977*X+.071516*X**2.)                        CEN13300
C                                                                       CEN13400
C                                                                       CEN13500
C                  CALC. OF OPERATING MANHOURS IF INCINERATION DISPOSAL CEN13600
C                  IS USED                                              CEN13700
C                                                                       CEN13800
      GO TO 210                                                         CEN13900
  200 OHRS=EXP(7.264153-.466246*X+.069552*X**2.)                        CEN14000
C                                                                       CEN14100
C                                                                       CEN14200
C                  CALC. OF MAINTENANCE MANHOURS, SUPPLIES AND CHEMICAL CEN14300
C                  COSTS                                                CEN14400
C                                                                       CEN14500
  210 XMHRS=EXP(5.997115-.493809*X+.070892*X**2.)                       CEN14600
      SUPP=EXP(-2.822519+.700948*X)*1000.                               CEN14700
      CHEM=DSOL*POLY*CPOLY                                              CEN14800
C                                                                       CEN14900
C                                                                       CEN15000
C                  OPERATING COST EQUATION                              CEN15100
C                                                                       CEN15200
      COSTO(N,1)=((OHRS+XMHRS)*DHR*(1.+PCT)+SUPP*EPI+CHEM)/SMATX(2,1)/36CEN15300
     150.                                                               CEN15400
C                                                                       CEN15500
C                                                                       CEN15600
C             ASSIGNMENT OF VALUES TO OMATX                             CEN15700
C                                                                       CEN15800
      OMATX(1,N)=CGPM                                                   CEN15900
      OMATX(2,N)=DSOL                                                   CEN16000
      OMATX(3,N)=AFC                                                    CEN16100
      OMATX(4,N)=CSIZE                                                  CEN16200
      OMATX(5,N)=CN                                                     CEN16300
C                                                                       CEN16400
C                                                                       CEN16500
C             PROCESS ENERGY INDICES                                    CEN16600
C                                                                       CEN16700
      FLOW(N)=SMATX(2,IS1)                                              CEN16800
      POW(N)=17.                                                        CEN16900
      RETURN                                                            CEN17000
      END                                                               CEN17100
```

SECTION 19

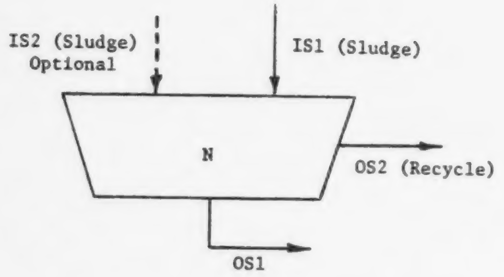
AEROBIC DIGESTION, AEROB

Subroutine Identification Number 18

Aerobic Digestion, AEROB

Rev. Date 8/1/77

1. Process symbol.



IS1: Primary sludge input stream

IS2: Secondary sludge input stream

OS1: Sludge output stream

OS2: Supernatant recycle output stream

N: User assigned number to the process

2. Input parameters and nominal values.

DMATX(1,N) = XL	Program control: this input variable is set equal to the user assigned process number (N) which the user assigned to the aeration (AERFS) process to allow the AEROB subroutine to use output parameters calculated in the aeration process. [varies]
DMATX(2,N) = XAFS	Program control: 0 = no final settler or sludge return pumps are required, 1 = a final settler and sludge return pumps are required with the aerobic digestion process. [1.]
DMATX(3,N) = DTA	Detention time for the aeration, days. [30.]
DMATX(4,N) = TSS1	Total suspended solids in OS1, mg/l. [40,000.]
DMATX(5,N) = TSS2	Total suspended solids in OS2, mg/l. [150.]
DMATX(6,N) = BOD2	Concentration of 5-day BOD in OS2, mg/l. [50.]
DMATX(7,N) = GSS	Overflow rate for the final settlers, gpd/sq ft. [150.]
DMATX(8,N) = HEAD	Pumping head of the sludge return pumps, ft. [30.]
DMATX(13,N) = ECF	Excess capacity factor for the final settlers. [1.2]
DMATX(14,N) = ECF	Excess capacity factor for the sludge return pumps. [1.25]
DMATX(15,N) = ECF	Excess capacity factor for the air blowers. [1.5]
DMATX(16,N) = ECF	Excess capacity factor for the aeration tank. [1.2]

3. Output parameters which are printed on computer output sheets.

XL = DMATX(1,N)	
XAFS = DMATX(2,N)	
DTA = DMATX(3,N)	
TSS1 = DMATX(4,N)	
TSS2 = DMATX(5,N)	
BOD2 = DMATX(6,N)	
GSS = DMATX(7,N)	
HEAD = DMATX(8,N)	
VAER = OMATX(1,N)	Volume of the aerator, cu ft/1000.
ACFM = OMATX(2,N)	Required size of the blower for supplying air to the aerator, cfm.
QPUMP = OMATX(3,N)	Volume of the return stream flow to the aerator, mgd.
AFS = OMATX(4,N)	Surface area of the final settler, sq ft/1000.
CCOST	Capital cost, [dollars].
COSTO	Operating and maintenance cost, [cents/1000 gal].
ACOST	Amortization cost, [cents/1000 gal].
TCOST	Total treatment cost, [cents/1000 gal].
ECF	Excess capacity factor.

4. Theory and functions - FORTRAN statement followed by equivalent algebraic equation.

```
SMAT(I) = SMATX(I,IS2)                                              AE002400
```

SMAT(I) = SMATX(I,IS2) [mg/1]

where I = 1,20 i.e. I,Q,SOC,SNBC,SON,SOP,SFM,SBOD,VSS,TSS,DOC,DNBC,
DN,DP,DFM,ALK,DBOD,NH3,NO3

```
TEMP1 = (SMAT(4)*2.13+(SMAT(8)+SMAT(17))*.65*.18)*SMAT(2)            AE002600
```

$$\text{TEMP1} = (2.13\text{SNBC}_{IS2}+0.65(\text{SBOD}_{IS2}+\text{DBOD}_{IS2})0.18)Q_{IS2} \qquad [\text{mg/1 MGD}]$$

```
TEMP2 = (OMATX(9,L)*.18+OMATX(10,L)*.0938+OMATX(11,L)+OMATX(12,L))*DMATX(7,L)*SMATX(2,IS1)
                                                                    AE002700
```

$$\text{TEMP2} = (0.18\text{OMATX}(9,L)+0.0938\text{OMATX}(10,L)+\text{OMATX}(11,L)+\text{OMATX}(12,L))*\text{DMATX}(7,L)*Q_{IS1}$$

[mg/1 MGD]

```
TEMP3 = SMAT(7)*SMAT(2)                                                AE002900
```

$$TEMP3 = SFM_{IS2}*Q_{IS2} \qquad [\,mg/1\ MGD\,]$$

```
TEMP4 = OMATX(13,L)*DMATX(7,L)*SMATX(2,IS1)                            AE003000
```

$$TEMP4 = OMATX(13,L)*DMATX(7,L)*Q_{IS1} \qquad [\,mg/1\ MGD\,]$$

```
SMATX(2,OS1) = ((TEMP1+TEMP2+TEMP3+TEMP4)-(SMATX(2,IS1)+SMAT(2))*      AE003500
  DMATX(5,N))/(DMATX(4,N)-DMATX(5,N))
```

$$Q_{OS1} = \frac{TEMP1+TEMP2+TEMP3+TEMP4-(Q_{IS1}+Q_{IS2})TSS2}{TSS1 - TSS2} \qquad [\,MGD\,]$$

```
SMATX(2,OS2) = SMATX(2,IS1)+SMAT(2)-SMATX(2,OS1)                       AE003700
```

$$Q_{OS2} = Q_{IS1}+Q_{IS2}-Q_{OS1} \qquad [\,MGD\,]$$

```
VOLPC = (TEMP1+TEMP2)/(TEMP1+TEMP2+TEMP3+TEMP4)                        AE003800
```

$$VOLPC = \frac{TEMP1+TEMP2}{TEMP1+TEMP2+TEMP3+TEMP4} \qquad [\text{no units}]$$

```
SMATX(9,OS1) = DMATX(4,N)*VOLPC                                        AE003900
```

$$VSS_{OS1} = TSS1*VOLPC \qquad [mg/1]$$

```
SMATX(7,OS1) = DMATX(4,N)-SMATX(9,OS1)                                 AE004000
```

$$SFM_{OS1} = TSS1 - VSS_{OS1} \qquad [mg/1]$$

```
SMATX(3,OS1) = SMATX(9,OS1)/2.13                                       AE004100
```

$$SOC_{OS1} = \frac{VSS_{OS1}}{2.13} \qquad [mg/1]$$

```
SMATX(4,OS1) = SMATX(3,OS1)                                            AE004200
```

$$SNBC_{OS1} = SOC_{OS1} \qquad [mg/1]$$

```
SMATX(5,OS1) = SMATX(3,OS1)/10.                                        AE004300
```

$$SON_{OS1} = \frac{SOC_{OS1}}{10} \qquad [mg/1]$$

```
SMATX(6,OS1) = SMATX(3,OS1)/100.                                       AE004400
```

$$SOP_{OS1} = \frac{SOC_{OS1}}{100} \qquad [mg/1]$$

```
SMATX(10,OS1) = DMATX(4,N)                                  AE004600
```

$TSS_{OS1} = TSS1$ [mg/l]

```
SMATX(10,OS2) = DMATX(5,N)                                  AE004700
```

$TSS_{OS2} = TSS2$ [mg/l]

```
SMATX(9,OS2) = SMATX(10,OS2)*VOLPC                          AE004800
```

$VSS_{OS2} = TSS2*VOLPC$ [mg/l]

```
SMATX(3,OS2) = SMATX(9,OS2)/2.13                            AE004900
```

$SOC_{OS2} = \frac{VSS_{OS2}}{2.13}$ [mg/l]

```
SMATX(4,OS2) = SMATX(3,OS2)                                 AE005000
```

$SNBC_{OS2} = SOC_{OS2}$ [mg/l]

```
SMATX(5,OS2) = SMATX(3,OS2)/10.                             AE005100
```

$SON_{OS2} = \frac{SOC_{OS2}}{10}$ [mg/l]

```
SMATX(6,OS2) = SMATX(3,OS2)/100.                            AE005200
```

$SOP_{OS2} = \frac{SOC_{OS2}}{100}$ [mg/l]

```
SMATX(7,OS2) = SMATX(10,OS2)-SMATX(9,OS2)                   AE005300
```

$SFM_{OS2} = TSS_{OS2} - VSS_{OS2}$ [mg/l]

```
SMATX(11,OS1) = (500.-SMATX(9,OS2)*1.42)/3.2                AE005500
```

$DOC_{OS1} = \frac{500-1.42VSS_{OS2}}{3.2}$ [mg/l]

```
SMATX(11,OS2) = SMATX(11,OS1)                               AE005600
```

$DOC_{OS2} = DOC_{OS1}$ [mg/l]

`SMATX(12,OS1) = SMATX(11,OS2)/2.` AE005700

$$DNBC_{OS1} = \frac{DOC_{OS2}}{2}$$ [mg/l]

`SMATX(12,OS2) = SMATX(12,OS1)` AE005800

$$DNBC_{OS2} = \frac{DOC_{OS2}}{2}$$ [mg/l]

`ENTN = SMATX(2,IS1)*(SMATX(5,IS1)+SMATX(13,IS1))+SMAT(2)*(SMAT(5)+SMAT(13))` AE005900

$$ENTN = Q_{IS1}(SON_{IS1}+DN_{IS1})+Q_{IS2}(SON_{IS2}+DN_{IS2})$$ [MGD mg/l]

`EXSN = SMATX(2,OS1)*SMATX(5,OS1)+SMATX(2,OS2)*SMATX(5,OS2)` AE006100

$$EXSN = (Q_{OS1}*SON_{OS1})+(Q_{OS2}*SON_{OS2})$$ [MGD mg/l]

`SMATX(13,OS1) = (ENTN-EXSN)/(SMATX(2,OS1)+SMATX(2,OS2))` AE006200

$$DN_{OS1} = \frac{ENTN-EXSN}{Q_{OS1}+Q_{OS2}}$$ [mg/l]

`SMATX(13,OS2) = SMATX(13,OS1)` AE006300

$$DN_{OS2} = DN_{OS1}$$ [mg/l]

`ENTP = SMATX(2,IS1)*(SMATX(6,IS1)+SMATX(14,IS1))+SMAT(2)*(SMAT(6)+SMAT(14))` AE006400

$$ENTP = Q_{IS1}(SOP_{IS1}+DP_{IS1})+Q_{IS2}(SOP_{IS2}+DP_{IS2})$$ [MGD mg/l]

`EXSP = SMATX(2,OS1)*SMATX(6,OS1)+SMATX(2,OS2)*SMATX(6,OS2)` AE006600

$$EXSP = (Q_{OS1}*SOP_{OS1})+(Q_{OS2}*SOP_{OS2})$$ [MGD mg/l]

`SMATX(14,OS2) = (ENTP-EXSP)/(SMATX(2,OS1)+SMATX(2,OS2))` AE006700

$$DP_{OS2} = \frac{ENTP-EXSP}{Q_{OS1}+Q_{OS2}}$$ [mg/l]

`SMATX(14,OS1) = SMATX(14,OS2)` AE006800

$$DP_{OS1} = DP_{OS2}$$ [mg/l]

`SMATX(15,OS1) = SMATX(15,IS1)` AE006900

$$DFM_{OS1} = DFM_{IS1}$$ [mg/l]

SMATX(15,OS2) = SMATX(15,IS1) AE007000

$DFM_{OS2} = DFM_{IS1}$ [mg/l]

SMATX(17,OS1) = DMATX(6,N)-50. AE007300

$DBOD_{OS1} = BOD2-50$ [mg/l]

SMATX(17,OS2) = SMATX(17,OS1) AE007400

$DBOD_{OS2} = BOD2-50$ [mg/l]

SMATX(18,OS1) = SMATX(18,IS1) AE007500

$NH3_{OS1} = NH3_{IS1}$ [mg/l]

SMATX(18,OS2) = SMATX(18,IS1) AE007600

$NH3_{OS2} = NH3_{IS1}$ [mg/l]

SMATX(19,OS1) = SMATX(19,IS1) AE007700

$NO3_{OS1} = NO3_{IS1}$ [mg/l]

SMATX(19,OS2) = SMATX(19,IS1) AE007800

$NO3_{OS2} = NO3_{IS1}$ [mg/l]

SMATX(20,OS1) = SMATX(20,IS1) AE007900

Future parameter [mg/l]

SMATX(20,OS2) = SMATX(20,IS1) AE008000

Future parameter [mg/l]

VAER1 = (SMATX(2,IS1)+SMAT(2))*DMATX(3,N)*1000./7.48*DMATX(16,N) AE008500

$$VAER_1 = \frac{(Q_{IS1}+Q_{IS2})1000DTA*ECF_a}{7.48} \quad \left[\frac{ft^3}{1000}\right]$$

VAER2 = (SMATX(2,IS1)*SMATX(10,IS1)+SMAT(2)*SMAT(10))*8.33/.05/1000.*DMATX(16,N)
AE008600

$$VAER2 = \frac{[(Q_{IS1}*TSS_{IS1})+(Q_{IS2}*TSS_{IS2})]8.33ECF_a}{0.05*1000} \quad \left[\frac{ft^3}{1000}\right]$$

```
BSIZE = 20.*VAER*DMATX(15,N)                                          AE009200
```

$$\mathrm{BSIZE} = 20\mathrm{VAER}*\mathrm{ECF}_b \qquad \left[\frac{\mathrm{ft}^3}{\mathrm{min}}\right]$$

```
AFS = (SMATX(2,IS1)+SMAT(2))*1000./DMATX(7,N)*DMATX(13,N)             AE009600
```

$$\mathrm{AFS} = \frac{1000(Q_{IS1}+Q_{IS2})\mathrm{ECF}_s}{\mathrm{GSS}} \qquad \left[\frac{\mathrm{ft}^2}{1000}\right]$$

```
DEMO = (SMATX(9,IS1)*SMATX(2,IS1)+SMAT(9)*SMAT(2)-TEMP1-TEMP2)*8.33*1.5  AE009700
```

$$\mathrm{DEMO} = 8.33[(\mathrm{VSS}_{IS1}*Q_{IS1})+(\mathrm{VSS}_{IS2}*Q_{IS2})-\mathrm{TEMP1}-\mathrm{TEMP2}]*1.5$$

```
CFM = DEMO/.075/.232/.05/1440.*DMATX(15,N)                            AE009900
```

$$\mathrm{CFM} = \frac{\mathrm{DEMO}*\mathrm{ECF}_b}{0.075*0.232*0.05*1440} \qquad \left[\frac{\mathrm{ft}^3}{\mathrm{min}}\right]$$

```
QPUMP = (SMATX(2,IS1)+SMAT(2))*DMATX(14,N)*1.5                        AE010400
```

$$\mathrm{QPUMP} = (Q_{IS1}+Q_{IS2})*1.5\mathrm{ECF}_p \qquad [\mathrm{MGD}]$$

Pump efficiency - Current values used in program; each can be changed by the replacement on punched card.

PEFF = 0.70 for $\mathrm{QPUMP} < 1.44$ MGD AE019000

PEFF = 0.74 for $\mathrm{QPUMP} < 10.08$ MGD AE019300

PEFF = 0.83 for $\mathrm{QPUMP} \geq 10.08$ MGD AE019500

References:

Patterson and Banker, 1971

5. Cost functions.

Aerator

a. Capital cost

Function of VAER

```
X = ALOG(VAER)                                                        AE011000
```

$$X = \ln \mathrm{VAER}$$

```
CCOST(N,1) = EXP(2.414380+.175682*X+.084742*X**2.-.002670*X**3.) *1000.  AE011100
```

$$\mathrm{CCOST} = 1000e^{2.414380+0.175682X+0.084742X^2-0.002670X^3} \qquad [\mathrm{dollars}]$$

b. Operating manhours, maintenance manhours and materials/supplies costs

(1) Operating manhours AE011700

`OHRS = 0` [hrs/yr]

(2) Maintenance manhours AE011800

`XMHRS = 0` [hrs/yr]

(3) Total materials and supplies AE011900

`TMSU = 0` [dollars/yr]

c. Total operating and maintenance costs AE012000

`COSTO(N,1) = 0` [cents/1000 gal]

Blower

a. Capital cost

Function of ACFM

`X = ALOG(ACFM/1000.)` AE012600

$$X = \ln \frac{ACFM}{1000}$$

`CCOST(N,2) = EXP(4.145454+.633339*X+.031939*X**2.-.002419*X**3.)*1000.` AE012700

$$CCOST = 1000e^{4.145454+0.633339X+0.031939X^2-0.002419X^3}$$ [dollars]

b. Operating manhours, maintenance manhours and materials/supplies costs

Function of $ACFM/ECF_b$

`X = ALOG(ACFM/1000./DMATX(15,N))` AE013400

$$X = \ln \frac{ACFM}{1000ECF_b}$$

(1) For $\frac{ACFM}{1000ECF_b} < 1$

(a) Operating manhours AE014100

`OHRS = 850` [hrs/yr]

(b) Maintenance manhours AE014200

`XMHRS = 350` [hrs/ yr]

(2) For $\frac{ACFM}{1000ECF_b} \geq 1$

(a) Operating manhours

```
OHRS = EXP(6.900586+.323725*X+.059093*X**2.-.004926*X**3.)     AE014400
```

$$OHRS = e^{6.900586+0.323725X+0.059093X^2-0.004926X^3} \quad [hrs/yr]$$

(b) Maintenance manhours

```
                                                                  AE014500
XMHRS = EXP(6.169937+.294853*X+.175999*X**2.-.040947*X**3.+.003300*X**4.)
```

$$XMHRS = e^{6.169937+0.294853X+0.175999X^2-0.040947X^3+0.003300X^4}$$

[hrs/yr]

(3) Blower horsepower

```
HP = ACFM/DMATX(15,N)*8.1*144./(33000.*.8)                        AE014700
```

$$HP = \frac{8.1ACFM*144}{ECF_b*33000*0.8} \quad [horsepower]$$

(4) Blower kilowatts

```
XKW = .8*HP                                                       AE014800
```

$$XKW = \frac{8.1ACFM*144}{33000\ ECF_b} \quad [kilowatts]$$

(5) Blower kilowatt years

```
XKWPY = XKW*24.*365.                                              AE014900
```

$$XKWPY = 24XKW*365 \quad [kwhr/yr]$$

(6) Energy cost

```
ECOST = XKWPY*DMATX(10,20)                                        AE015000
```

$$ECOST = XKWPY*CKWH \quad [dollars/yr]$$

(7) Service cost

```
SCOST = EXP(.621382+.482047*X)*1000.                              AE015100
```

$$SCOST = 1000e^{0.621382+0.482047X} \quad [dollars/yr]$$

c. Total operating and maintenance costs

```
                                                         AE015600
COSTO(N,2) = ((OHRS+XMHRS)*DHR*(1+PCT)+SCOST*WPI+ECOST)/SMATX(2,1)/3650.
```

$$\text{COSTO} = \frac{\text{(OHRS+XMHRS) DHR (1+PCT)+(SCOST*WPI)+ECOST}}{Q_{\text{Plant Inf.}} * 3650} \qquad \text{[cents/1000 gal]}$$

Sludge pumps

a. Capital cost

Function of QPUMP

```
X = ALOG(QPUMP)                                          AE016700
```

$X = \ln \text{QPUMP}$

(1) $\text{QPUMP} < 5$ AE016500

CCOST = 20000 [dollars]

(2) $\text{QPUMP} \geq 5$ AE016800

```
CCOST(N,3) = EXP(3.481553+.377485*X+.093349*X**2.-.006222*X**3.)*1000.
```

$$\text{CCOST} = 1000e^{3.481553+0.377485X+0.093349X^2-0.006222X^3} \qquad \text{[dollars]}$$

b. Operating manhours, maintenance manhours and materials/supplies costs

Function of QPUM[illegible]CF$_p$

```
X = ALOG(QPUMP/DMATX(14,N))                              AE018500
```

$X = \ln \frac{\text{QPUMP}}{\text{ECF}_p}$

(1) Operating manhours

(a) $\frac{\text{QPUMP}}{\text{ECF}_p} < 7$ AE018100

OHRS = 400 [hrs/yr]

(b) $\frac{\text{QPUMP}}{\text{ECF}_p} \geq 7$ AE018600

```
OHRS = EXP(6.097269+.253066*X-.193659*X**2.+.078201*X**3.-.006680*X**4.)
```

$$\text{OHRS} = e^{6.097269+0.253066X-0.193659X^2+0.078201X^3-0.006680X^4} \qquad \text{[hrs/yr]}$$

(2) Maintenance manhours

(a) $\frac{\mathrm{QPUMP}}{\mathrm{ECF}_p} < 7$ AE018200

```
XMHRS = 250
```

[hrs/yr]

(b) $\frac{\mathrm{QPUMP}}{\mathrm{ECF}_p} \geq 7$ AE018800

```
XMHRS = EXP(5.911541-.013158*X+.076643*X**2.)
```

$$\mathrm{XMHRS} = e^{5.911541-0.013158X+0.076643X^2}$$

[hrs/yr]

(3) Total materials and sunplies

(a) $\frac{\mathrm{QPUMP}}{\mathrm{ECF}_p} < 7$ AE018300

```
TMSU = 200.+(DMATX(8,N)/30.)*400.
```

$$\mathrm{TMSU} = 200 + \frac{400\mathrm{HEAD}}{30}$$

[dollars/yr]

(b) $\frac{\mathrm{QPUMP}}{\mathrm{ECF}_p} \geq 7$ AE019900

```
TMSU = ECOST+SCOST*WPI
```

$$\mathrm{TMSU} = \mathrm{ECOST}+(\mathrm{SCOST}*\mathrm{WPI})$$

[dollars/yr]

(4) Kilowatt hrs per year

AE019600

```
YRKW = QPUMP*1000000.*DMATX(8,N)/1440./3960./PEFF/.9*.7457*24.*365.
```

$$\mathrm{YRKW} = \frac{1000000\mathrm{QPUMP}*0.7457\mathrm{HEAD}*24*365}{1440*3960\mathrm{PEFF}*0.9}$$

[kwhr/yr]

(5) Energy cost

AE019700

```
ECOST = YRKW*DMATX(10,20)
```

$$\mathrm{ECOST} = \mathrm{YRKW}*\mathrm{CKWH}$$

[dollars/yr]

(6) Service cost

AE019800

```
SCOST = EXP(5.851743+.301610*X+.197183*X**2.-.017962*X**3.)
```

$$\mathrm{SCOST} = e^{5.851743+0.301610X+0.197183X^2-0.017962X^3}$$

[dollars/yr]

c. Total operating and maintenance costs AE020400

`COSTO(N,3) = ((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU)/SMATX(2,1)/3650.`

$$\mathrm{COSTO} = \frac{\mathrm{(OHRS+XMHRS)DHR(1+PCT)+TMSU}}{Q_{\mathrm{Plant\ Inf.}} * 3650} \qquad \text{[cents/1000 gal]}$$

Final settler

a. Capital cost

Function of AFS

`X = ALOG(AFS)` AE021300

$$X = \ln \mathrm{AFS}$$

(1) AFS < 1 acre AE021100

CCOST = 25000 [dollars]

(2) AFS $\geq$ 1 acre AE021400

`CCOST(N,4) = EXP(3.716354+.389861*X+.084560*X**2.-.004718*X**3.)*1000.`

$$\mathrm{CCOST} = 1000e^{3.716354+0.389861X+0.084560X^2-0.004718X^3} \qquad \text{[dollars]}$$

b. Operating manhours, maintenance manhours and materials/supplies costs

Function of $\mathrm{AFS/ECF_s}$

`X = ALOG(AFS/DMATX(13,N))` AE023000

$$X = \ln \frac{\mathrm{AFS}}{\mathrm{ECF_s}}$$

(1) Operating manhours

(a) $\frac{\mathrm{AFS}}{\mathrm{ECF_s}} < 1$ AE022600

OHRS = 300 [hrs/yr]

(b) $\frac{\mathrm{AFS}}{\mathrm{ECF_s}} \geq 1$ AE023100

`OHRS = EXP(5.846565+.254813*X+.113703*X**2.-.010942*X**3.)`

$$\mathrm{OHRS} = e^{5.846565+0.254813X+0.113703X^2-0.010942X^3} \qquad \text{[hrs/yr]}$$

(2) Maintenance manhours

(a) $\frac{AFS}{ECF_s} < 1$ AE022700

$XMHRS = 150$ [hrs/yr]

(b) $\frac{AFS}{ECF_s} \geq 1$ AE023200

```
XMHRS = EXP(5.273419+.228329*X+.122646*X**2.-.011672*X**3.)
```

$$XMHRS = e^{5.273419+0.228329X+0.122646X^2-0.011672X^3}$$ [hrs/yr]

(3) Total materials and supplies

(a) $\frac{AFS}{ECF_s} < 1$ AE022800

$TMSU = 125$ [dollars/yr]

(b) $\frac{AFS}{ECF_s} \geq 1$ AE023300

```
TMSU = EXP(5.669881+.750799*X)
```

$$TMSU = e^{5.669881+0.750799X}$$ [dollars/yr]

(4) Total operating and maintenance costs AE023800

```
COSTO(N,4) = ((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.
```

$$COSTO = \frac{(OHRS+XMHRS)DHR(1+PCT)+(TMSU*WPI)}{Q_{Plant\ Inf.} * 3650}$$ [cents/1000 gal]

```
C
C              AEROBIC DIGESTION
C              PROCESS IDENTIFICATION NUMBER  18
C
      SUBROUTINE AEROB
C
C
C              COMMON INITIAL STATEMENTS
C
      INTEGER OS1,OS2
      DIMENSION SMAT(20)
      COMMON SMATX(20,30),TMATX(20,30),DMATX(20,20),OMATX(20,20),IP(20),
     1INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),ACOST(20,5)
     2,TCOST(20,5),DHR,PCT,WPI,CLAND,DLAND,FLOW(25),POW(25),TKWHD(25)
C
C
C              PROCESS RELATIONSHIPS REQD. TO CALC. EFFLUENT STREAM
C              CHARACTERISTICS
C
      DO 10 I=1,20
   10 SMAT(I)=0.
      IF (IS2) 20,40,20
   20 DO 30 I=1,20
   30 SMAT(I)=SMATX(I,IS2)
   40 L=DMATX(1,N)
      TEMP1=(SMAT(4)*2.13+(SMAT(8)+SMAT(17))*.65*.18)*SMAT(2)
      TEMP2=(OMATX(9,L)*.18+OMATX(10,L)*.0938+OMATX(11,L)+OMATX(12,L))*D
     1MATX(7,L)*SMATX(2,IS1)
      TEMP3=SMAT(7)*SMAT(2)
      TEMP4=OMATX(13,L)*DMATX(7,L)*SMATX(2,IS1)
C
C
C              EFFLUENT STREAM CALCULATIONS
C
      SMATX(2,OS1)=((TEMP1+TEMP2+TEMP3+TEMP4)-(SMATX(2,IS1)+SMAT(2))*DMA
     1TX(5,N))/(DMATX(4,N)-DMATX(5,N))
      SMATX(2,OS2)=SMATX(2,IS1)+SMAT(2)-SMATX(2,OS1)
      VOLPC=(TEMP1+TEMP2)/(TEMP1+TEMP2+TEMP3+TEMP4)
      SMATX(9,OS1)=DMATX(4,N)*VOLPC
      SMATX(7,OS1)=DMATX(4,N)-SMATX(9,OS1)
      SMATX(3,OS1)=SMATX(9,OS1)/2.13
      SMATX(4,OS1)=SMATX(3,OS1)
      SMATX(5,OS1)=SMATX(3,OS1)/10.
      SMATX(6,OS1)=SMATX(3,OS1)/100.
      SMATX(8,OS1)=0.
      SMATX(10,OS1)=DMATX(4,N)
      SMATX(10,OS2)=DMATX(5,N)
      SMATX(9,OS2)=SMATX(10,OS2)*VOLPC
      SMATX(3,OS2)=SMATX(9,OS2)/2.13
      SMATX(4,OS2)=SMATX(3,OS2)
      SMATX(5,OS2)=SMATX(3,OS2)/10.
      SMATX(6,OS2)=SMATX(3,OS2)/100.
      SMATX(7,OS2)=SMATX(10,OS2)-SMATX(9,OS2)
      SMATX(8,OS2)=50.
      SMATX(11,OS1)=(500.-SMATX(9,OS2)*1.42)/3.2
      SMATX(11,OS2)=SMATX(11,OS1)
      SMATX(12,OS1)=SMATX(11,OS2)/2.
      SMATX(12,OS2)=SMATX(12,OS1)
```

```
C
      X=ALOG(ACFM/1000.)
      CCOST(N,2)=EXP(4.145454+.633339*X+.031939*X**2.-.002419*X**3.)*100
     10.
C
C
C             CALC. OF OPERATING COSTS FOR BLOWER BASED ON DESIGN
C             CAPACITY ALONE, DOES NOT INCLUDE EXCESS CAPACITY
C
      X=ALOG(ACFM/1000./DMATX(15,N))
C
C
C                    CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS
C                    AND ELECTRICAL POWER AND SUPPLY COSTS
C
      IF (ACFM/1000./DMATX(15,N)-1.) 140,150,150
  140 OHRS=850.
      XMHRS=350.
      GO TO 160
  150 OHRS=EXP(6.900586+.323725*X+.059093*X**2.-.004926*X**3.)
      XMHRS=EXP(6.169937+.294853*X+.175999*X**2.-.040947*X**3.+.003300*X
     1**4.)
  160 HP=ACFM/DMATX(15,N)*8.1*144./(33000.*.8)
      XKW=.8*HP
      XKWPY=XKW*24.*365.
      ECOST=XKWPY*DMATX(10,20)
      SCOST=EXP(.621382+.482047*X)*1000.
C
C
C                    OPERATING COST EQUATION
C
      COSTO(N,2)=((OHRS+XMHRS)*DHR*(1.+PCT)+SCOST*WPI+ECOST)/SMATX(2,1)/
     13650.
C
C
C             CALC. OF CAPITAL COSTS FOR SLUDGE RETURN PUMPS BASED
C             ON DESIGN PLUS EXCESS CAPACITY
C
      IF (DMATX(2,N)) 170,350,170
  170 IF (QPUMP-.5) 180,190,190
  180 CCOST(N,3)=20000.
      GO TO 200
  190 X=ALOG(QPUMP)
      CCOST(N,3)=EXP(3.481553+.377485*X+.093349*X**2.-.006222*X**3.)*100
     10.
C
C
C             CALC. OF OPERATING COSTS FOR SLUDGE RETURN PUMPS BASED
C             ON DESIGN CAPACITY ALONE, DOES NOT INCLUDE EXCESS
C             CAPACITY
C
C
C                    CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS
C                    AND MATERIALS AND SUPPLIES
C
  200 IF (QPUMP/DMATX(14,N)-.7) 210,220,220
  210 OHRS=400.
      XMHRS=250.
      TMSU=200.+(DMATX(8,N)/30.)*400.
      GO TO 280
  220 X=ALOG(QPUMP/DMATX(14,N))
      OHRS=EXP(6.097269+.255066*X-.193659*X**2.+.078201*X**3.-.006680*X*
     1*4.)
      XMHRS=EXP(5.911541-.013158*X+.076643*X**2.)
      ENTN=SMATX(2,IS1)*(SMATX(5,IS1)+SMATX(13,IS1))+SMAT(2)*(SMAT(5)+SMAE005900
     1AT(13))                                                           AE006000
      EXSN=SMATX(2,OS1)*SMATX(5,OS1)+SMATX(2,OS2)*SMATX(5,OS2)          AE006100
      SMATX(13,OS1)=(ENTN-EXSN)/(SMATX(2,OS1)+SMATX(2,OS2))             AE006200
      SMATX(13,OS2)=SMATX(13,OS1)                                       AE006300
      ENTP=SMATX(2,IS1)*(SMATX(6,IS1)+SMATX(14,IS1))+SMAT(2)*(SMAT(6)+SMAE006400
     1AT(14))                                                           AE006500
      EXSP=SMATX(2,OS1)*SMATX(6,OS1)+SMATX(2,OS2)*SMATX(6,OS2)          AE006600
      SMATX(14,OS2)=(ENTP-EXSP)/(SMATX(2,OS1)+SMATX(2,OS2))             AE006700
      SMATX(14,OS1)=SMATX(14,OS2)                                       AE006800
      SMATX(15,OS1)=SMATX(15,IS1)                                       AE006900
      SMATX(15,OS2)=SMATX(15,IS1)                                       AE007000
      SMATX(16,OS1)=300.                                                AE007100
      SMATX(16,OS2)=300.                                                AE007200
      SMATX(17,OS1)=DMATX(6,N)-50.                                      AE007300
      SMATX(17,OS2)=SMATX(17,OS1)                                       AE007400
      SMATX(18,OS1)=SMATX(18,IS1)                                       AE007500
      SMATX(18,OS2)=SMATX(18,IS1)                                       AE007600
      SMATX(19,OS1)=SMATX(19,IS1)                                       AE007700
      SMATX(19,OS2)=SMATX(19,IS1)                                       AE007800
      SMATX(20,OS1)=SMATX(20,IS1)                                       AE007900
      SMATX(20,OS2)=SMATX(20,IS1)                                       AE008000
C                                                                       AE008100
C                                                                       AE008200
C               CALC. OF OUTPUT SIZES AND QUANTITIES                    AE008300
C                                                                       AE008400
      VAER1=(SMATX(2,IS1)+SMAT(2))*DMATX(3,N)*1000./7.48*DMATX(16,N)    AE008500
      VAER2=(SMATX(2,IS1)*SMATX(10,IS1)+SMAT(2)*SMAT(10))*8.33/.05/1000.AE008600
     1*DMATX(16,N)                                                      AE008700
      IF (VAER1-VAER2) 50,60,60                                         AE008800
   50 VAER=VAER2                                                        AE008900
      GO TO 70                                                          AE009000
   60 VAER=VAER1                                                        AE009100
   70 BSIZE=20.*VAER*DMATX(15,N)                                        AE009200
      IF (DMATX(2,N)) 90,80,90                                          AE009300
   80 AFS=0.                                                            AE009400
      GO TO 100                                                         AE009500
   90 AFS=(SMATX(2,IS1)+SMAT(2))*1000./DMATX(7,N)*DMATX(13,N)           AE009600
  100 DEMO=(SMATX(9,IS1)*SMATX(2,IS1)+SMAT(9)*SMAT(2)-TEMP1-TEMP2)*8.33*AE009700
     11.5                                                               AE009800
      CFM=DEMO/.075/.232/.05/1440.*DMATX(15,N)                          AE009900
      IF (BSIZE-CFM) 110,120,120                                        AE010000
  110 ACFM=CFM                                                          AE010100
      GO TO 130                                                         AE010200
  120 ACFM=BSIZE                                                        AE010300
  130 QPUMP=(SMATX(2,IS1)+SMAT(2))*DMATX(14,N)*1.5                      AE010400
C                                                                       AE010500
C                                                                       AE010600
C               CALC. OF CAPITAL COSTS FOR AERATION TANK BASED ON DESIGN AE010700
C               PLUS EXCESS CAPACITY                                    AE010800
C                                                                       AE010900
      X=ALOG(VAER)                                                      AE011000
      CCOST(N,1)=EXP(2.414380+.175682*X+.084742*X**2.-.002670*X**3.)*100AE011100
     10.                                                                AE011200
C                                                                       AE011300
C                                                                       AE011400
C               CALC. OF OPERATING COSTS FOR AERATION TANK              AE011500
C                                                                       AE011600
      OHRS=0.                                                           AE011700
      XMHRS=0.                                                          AE011800
      TMSU=0.                                                           AE011900
      COSTO(N,1)=0.                                                     AE012000
C                                                                       AE012100
C                                                                       AE012200
C               CALC. OF CAPITAL COSTS FOR BLOWER BASED ON DESIGN PLUS  AE012300
C               EXCESS CAPACITY                                         AE012400
```

```
      IF (QPUMP-1.44) 230,240,240                                       AE018900
  230 PEFF=.70                                                          AE019000
      GO TO 270                                                         AE019100
  240 IF (PEFF-10.06) 250,260,260                                       AE019200
  250 PEFF=.74                                                          AE019300
      GO TO 270                                                         AE019400
  260 PEFF=.83                                                          AE019500
  270 YRKW=QPUMP*1000000.*DMATX(8,N)/1440./3960./PEFF/.9*.7457*24.*365. AE019600
      ECOST=YRKW*DMATX(10,20)                                           AE019700
      SCOST=EXP(5.851743+.301610*X+.197183*X**2.-.017962*X**3.)         AE019800
      TMSU=ECOST+SCOST*WPI                                              AE019900
C                                                                       AE020000
C                                                                       AE020100
C                  OPERATING COST EQUATION                              AE020200
C                                                                       AE020300
  280 COSTO(N,3)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU)/SMATX(2,1)/3650.      AE020400
C                                                                       AE020500
C                                                                       AE020600
C             CALC. OF CAPITAL COSTS FOR FINAL SETTLER BASED ON DESIGN  AE020700
C             PLUS EXCESS CAPACITY                                      AE020800
C                                                                       AE020900
      IF (AFS-1.) 290,300,300                                           AE021000
  290 CCOST(N,4)=25000.                                                 AE021100
      GO TO 310                                                         AE021200
  300 X=ALOG(AFS)                                                       AE021300
      CCOST(N,4)=EXP(3.716354+.389861*X+.084560*X**2.-.004718*X**3.)*100AE021400
     10.                                                                AE021500
C                                                                       AE021600
C                                                                       AE021700
C             CALC. OF OPERATING COSTS FOR FINAL SETTLER BASED ON       AE021800
C             DESIGN CAPACITY ALONE, DOES NOT INCLUDE EXCESS CAPACITY   AE021900
C                                                                       AE022000
C                                                                       AE022100
C                  CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS    AE022200
C                  AND MATERIALS AND SUPPLIES                           AE022300
C                                                                       AE022400
  310 IF (AFS/DMATX(13,N)-1.) 320,330,330                               AE022500
  320 OHRS=300.                                                         AE022600
      XMHRS=150.                                                        AE022700
      TMSU=125.                                                         AE022800
      GO TO 340                                                         AE022900
  330 X=ALOG(AFS/DMATX(13,N))                                           AE023000
      OHRS=EXP(5.846565+.254813*X+.113703*X**2.-.010942*X**3.)          AE023100
      XMHRS=EXP(5.273419+.228329*X+.122646*X**2.-.011672*X**3.)         AE023200
      TMSU=EXP(5.669881+.750799*X)                                      AE023300
C                                                                       AE023400
C                                                                       AE023500
C                  OPERATING COST EQUATION                              AE023600
C                                                                       AE023700
  340 COSTO(N,4)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.  AE023800
C                                                                       AE023900
C                                                                       AE024000
C             ASSIGNMENT OF VALUES TO OMATX                             AE024100
C                                                                       AE024200
  350 OMATX(1,N)=VAER                                                   AE024300
      OMATX(2,N)=ACFM                                                   AE024400
      OMATX(3,N)=QPUMP                                                  AE024500
      OMATX(4,N)=AFS                                                    AE024600
C                                                                       AE024700
C                                                                       AE024800
C             PROCESS ENERGY INDICES                                    AE024900
C                                                                       AE025000
      FLOW(N)=SMATX(2,IS1)                                              AE025100
      POW(N)=18.                                                        AE025200
      RETURN                                                            AE025300
      END                                                               AE025400
```

SECTION 20

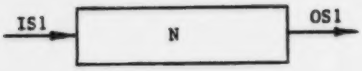
POST AERATION, POSTA

Subroutine Identification Number 19

Rev. Date 8/1/77

Post Aeration, POSTA

1. Process symbol.



IS1: Liquid input stream
OS1: Liquid output stream
N: User assigned number to the process

2. Input parameters and nominal values.

DMATX(1,N) = ITYPE	Program control: -1 = mechanical aeration system is used, 0 = diffused air aeration system is used (plug flow), +1 = diffused air aeration system is used (complete mix).[-1.]
DMATX(2,N) = L	Program control: set equal to the user assigned process number (N) given to the aeration process (AERFS) to allow the POSTA subroutine to use output parameters calculated in the aeration process.[varies].
DMATX(3,N) = DOIN	Dissolved oxygen concentration in the influent stream to the post aeration process, mg/l.[1.]
DMATX(4,N) = DOUT	Dissolved oxygen concentration in the effluent stream from the post aeration process, mg/l.[4.]
DMATX(5,N) = TL	Water temperature, degrees Centigrade.[20.]
DMATX(6,N) = TD	Tank depth (for diffused air only), ft.[15.]
DMATX(7,N) = TW	Tank width (for diffused air only), ft.[24.]
DMATX(8,N) = AERFO	Aeration efficiency at standard conditions (for diffused air only), fraction.[.08]
DMATX(9,N) = HPHRO	Efficiency measure for the mechanical aerators, lb of oxygen transferred per hp-hr.[3.5]
DMATX(10,N) = ALT	Altitude of the plant site above sea level. ft.[0.]
DMATX(11,N) = CFMDF	Capacity of each air diffuser, scfm.[15.]
DMATX(12,N) = DIFFT	Number of diffusers per foot of tank length.[1.]
DMATX(13,N) = DD	Depth of diffusers below the water surface, ft.[13.]
DMATX(15,N) = ECF	Excess capacity factor for the air supply system.[1.]
DMATX(16,N) = ECF	Excess capacity factor for the aeration basin.[1.]

3. Output parameters which are printed on computer output sheets.

ITYPE = DMATX(1,N)	
L = DMATX(2,N)	
DOIN = DMATX(3,N)	
DOUT = DMATX(4,N)	
TL = DMATX(5,N)	
TD = DMATX(6,N)	
TW = DMATX(7,N)	
AERFO = DMATX(8,N)	
HPHRO = DMATX(9,N)	
ALT = DMATX(10,N)	
CFMDF = DMATX(11,N)	
DIFFT = DMATX(12,N)	
DD = DMATX(13,N)	
VAER = OMATX(1,N)	Volume of the post aeration basin, cu ft/1000.
CFM = OMATX(2,N)	Air requirement for the diffusers, cfm.
HP = OMATX(3,N)	Installed brake horsepower for mechanical aeration, hp.
TMIN = OMATX(4,N)	Detention time in the post aeration basin, minutes.
VMG = OMATX(5,N)	Volume of the post aeration basin, million gallons.
AERFF = OMATX(6,N)	Aeration efficiency corrected to plant conditions.
CLEN = OMATX(7,N)	Aeration channel length (plug flow), ft.
HPI = OMATX(8,N)	Installed brake horsepower (HP) rounded off to the next higher available size mechanical aerator, hp.
XN = OMATX(9,N)	Number of mechanical aerators required.
THP = OMATX(10,N)	Total mechanical aeration horsepower required (HPI*XN), hp.
WIDTH = OMATX(11,N)	Mechanical aeration basin width, ft.

DEPTH = OMATX(12,N)	Mechanical aeration basin depth, ft.	
TLEN = OMATX(13,N)	Aeration basin length (diffused air, complete mix), ft.	
CCOST	Capital cost,	[dollars].
COSTO	Operating and maintenance cost,	[cents/1000gal].
ACOST	Amortization cost,	[cents/1000gal].
TCOST	Total treatment cost,	[cents/1000gal].
ECF	Excess capacity factor,	

References:

Smith, Eilers and Hall, 1973

4. Theory and functions - FORTRAN statement followed by equivalent algebraic equation.

```
S = SMATX(8,IS1)+SMATX(17,IS1)                                   POS05200
```

$$S = SBOD_{IS1}+DBOD_{IS1} \qquad [mg/l]$$

```
XA = OMATX(9,L)*OMATX(3,L)                                       POS05300
```

$$XA = OMATX(9,L)*OMATX(3,L) \qquad [mg/l]$$

```
SMATX(I,OS1) = SMATX(I,IS1)                                      POS03900
```

$$SMATX(I,OS1) = SMATX(I,IS1) \qquad [mg/l]$$

where I = 2,20 i.e. Q.SOC,SNBC,SON,SOP,SFM,SBOD,VSS,TSS,DOC,DNBC,DN,DP,DFM,ALK,DBOD, NH3,NO3

```
CSS = 14.652-.410220*TL+.007991*TL**2.-.000078*TL**3.            POS07200
```

$$CSS = 14.652-0.410220TL+0.007991TL^2-0.000078TL^3 \qquad [mg/l]$$

```
RP = (760.-.025*ALT)/760.                                        POS07300
```

$$RP = \frac{760-0.025ALT}{760} \qquad [no\ units]$$

`CSW = RP*CSS*BETA` POS07400

$$CSW = RP*CSS*BETA$$ [mg/l]

`AERK1 = .31942*(CSW-DOUT)*HPHRO*ALPHA*1.025**(TL-20.)` POS07700

$$AERK1 = 0.31942(CSW-DOUT)*HPHRO*ALPHA*(1.025)^{TL-20}$$ [1/day]

`AERK2 = .58*CAER*XA*S/CY+1.16*CE*XA` POS07800

$$AERK2 = \frac{0.58CAER*XA*S}{CY} + (1.16CE*XA)$$ $[\frac{mg/l}{day}]$

`HP = (SMATX(2,IS1)*(DOUT-DOIN)+AERK2*VMG)/AERK1*DMATX(15,N)` POS08100

$$HP = \frac{[Q_{IS1}*(DOUT-DOIN)+(AERK2*VMG)]ECF}{AERK1}$$ [horsepower]

`VCF = (17.+.53*HP)**2.*(5.+.07*HP)` POS08200

$$VCF = (17+0.53HP)^2*(5+0.07HP)$$ $[ft^3]$

`VMG = VCF*7.48/1000000.*DMATX(16,N)` POS08400

$$VMG = \frac{7.48VCF*ECF}{1000000}$$ [MG]

`VDEL = ABS(VMG-VMGP)` POS08500

$$VDEL = \left| VMG-VMGP \right|$$ [MG]

`HP1 = SIZE(I)` (For $HP \leq$ size (I)) POS09300

$$HP1 = SIZE(I)$$ [horsepower]

where I = 1,14

`XN = HP /150.` POS09800

$$XN = \frac{HP}{150}$$ [number]

```
THP = HP1*XN                                      POS10100
```

$$THP = HP1*XN \qquad [\text{horsepower}]$$

```
WIDTH = 17.+.53*HP1                               POS10200
```

$$WIDTH = 17+0.53HP1 \qquad [\text{ft}]$$

```
DEPTH = 5.+.07*HP1                                POS10300
```

$$DEPTH = 5+0.07HP1 \qquad [\text{ft}]$$

```
VCF = DEPTH*WIDTH**2.                             POS10400
```

$$VCF = DEPTH*WIDTH^2 \qquad [\text{ft}^3]$$

```
VMG = (VCF*7.48/1000000.)*XN                      POS10500
```

$$VMG = \frac{7.48VCF*XN}{1000000} \qquad [\text{MG}]$$

```
HPMG = THP/VMG                                    POS10600
```

$$HPMG = \frac{THP}{VMG} \qquad [\frac{\text{hp}}{\text{MG}}]$$

```
DAYS = VMG/SMATX(2,IS1)                           POS10700
```

$$DAYS = \frac{VMG}{Q_{IS1}} \qquad [\text{days}]$$

```
TMIN = DAYS*1440.                                 POS10800
```

$$TMIN = 1440\ DAYS \qquad [\text{min}]$$

```
VAER = VMG*1000./7.48                             POS10900
```

$$VAER = \frac{1000VMG}{7.48} \qquad [\frac{\text{ft}^3}{1000}]$$

```
CFMMG = CFMDF*DIFFT*1000000./TD/TW/7.48                         POS11100
```

$$CFMMG = \frac{CFMDF*DIFFT*1000000}{7.48TD*TW} \qquad [\frac{cfm}{MG}]$$

```
AERFF = AERFO*(DD/13.)**.66666*(8./CFMDF)**.2                   POS11200
```

$$AERFF = AERFO* (\frac{DD}{13})^{0.66666} *(\frac{8}{CFMDF})^{0.2} \qquad [\text{no units}]$$

```
AERK1 = .33347*CFMMG*AERFF*ALPHA*1.025**(TL-20.)                POS11300
```

$$AERK1 = 0.33347CFMMG*AERFF*ALPHA*(1.025)^{TL-20} \qquad [1/day]$$

```
AERK2 = .58*CAER*XA*S/CY-1.16*CE*XA                             POS11400
```

$$AERK2 = \frac{0.58*CAER*XA*S}{CY} -(1{,}16CE*XA) \qquad [\frac{mg/l}{day}]$$

```
TEMP = (AERK1*(CSW-DOUT)-AERK2)/(AERK1*(CSW-DOIN)-AERK2)         POS11500
```

$$TEMP = \frac{AERK1(CSW-DOUT)-AERK2}{AERK1(CSW-DOIN)-AERK2} \qquad [\text{no units}]$$

```
DAYS = -1.*ALOG(TEMP)/AERK1                                     POS11600
```

$$DAYS = -\frac{\ln TEMP}{AERK1} \qquad [days]$$

```
TMIN = DAYS*1440.                                               POS11700
```

$$TMIN = 1440\ DAYS \qquad [min]$$

```
VFM = SMATX(2,IS1)*92.84/TD/TW                                  POS11800
```

$$VFM = \frac{92.84Q_{IS1}}{TD*TW} \qquad [ft/min]$$

```
CLEN = VFM*TMIN                                                 POS11900
```

$$CLEN = \frac{92.84Q_{IS1}*TMIN}{TD*TW} \qquad [ft]$$

```
CFM = CLEN*CFMDF*DIFFT*DMATX(15,N)                                     POS12000
```

$$\text{CFM} = \text{CLEN*CFMDF*DIFFT*ECF}_{s} \qquad [\text{cfm}]$$

```
CFMMG = CFMDF*DIFFT*1000000./TD/TW/7.48                                POS12200
```

$$\text{CFMMG} = \frac{\text{CFMDF*1000000DIFFT}}{\text{7.48TD*TW}} \qquad [\text{ft}^3/\text{MG}]$$

```
AERFF = AERFO*(DD/13.)**.66666*(8./CFMDF)**.2                          POS12300
```

$$\text{AERFF} = \text{AERFO}\left(\frac{\text{DD}}{13}\right)^{0.66666} * \left(\frac{8}{\text{CFMDF}}\right)^{0.2} \qquad [\text{no units}]$$

```
AERK1 = .33347*CFMMG*AERFF*ALPHA*1.025**(TL-20.)                       POS12400
```

$$\text{AERK1} = \text{0.33347CFMMG*AERFF*ALPHA*}[1.025]^{\text{TL}-20} \qquad [\text{1/days}]$$

```
AERK2 = .58*CAER*XA*S/CY-1.16*CE*XA                                    POS12500
```

$$\text{AERK2} = \frac{\text{0.58CAER*XA*S}}{\text{CY}} - (\text{1.16CE*XA}) \qquad \left[\frac{\text{mg/l}}{\text{day}}\right]$$

```
VMG = SMATX(2,IS1)*(DOUT-DOIN)/(AERK1*(CSW-DOUT)-AERK2)*DMATX(16,N)    POS12600
```

$$\text{VMG} = \frac{Q_{\text{IS1}}(\text{DOUT-DOIN})\text{ECF}_{b}}{\text{AERK1(CSW-DOUT)-AERK2}} \qquad [\text{MG}]$$

```
DAYS = VMG/SMATX(2,IS1)                                                POS12700
```

$$\text{DAYS} = \frac{\text{VMG}}{Q_{\text{IS1}}} \qquad [\text{days}]$$

```
TMIN = DAYS*1440.                                                      POS12800
```

$$\text{TMIN} = \text{1440DAYS} \qquad [\text{min}]$$

```
TLEN = VMG*1000000./TD/TW/7.48                                         POS12900
```

$$\text{TLEN} = \frac{\text{1000000VMG}}{\text{7.48TD*TW}} \qquad [\text{ft}]$$

VAER = VMG*1000./7.48 POS13000

$$VAER = \frac{1000VMG}{7.48} \qquad [\frac{ft^3}{1000}]$$

CFM = CFMMG*VMG*DMATX(15,N) POS13100

$$CFM = CFMMG*VMG*ECF_s \qquad [cfm]$$

5. Cost functions.

Post aeration basin

a. Capital cost

Function of VAER

X = ALOG(VAER) POS14300

$$X = \ln VAER$$

CCOST(N,1) = EXP(2.180040+.351346*X+.064188*X**2.-.003403*X**3.)*1000. POS14400

$$CCOST = 1000e^{2.180040+0.351346X+0.064188X^2-0.003403X^3} \qquad [dollars]$$

b. Operating manhours, maintenance manhours and materials/supplies costs

(1) Operating manhours POS15200

OHRS = 0 [hrs/yr]

(2) Maintenance manhours POS15300

XMHRS = 0 [hrs/yr]

(3) Total materials and supplies POS15400

TMSU = 0 [dollars/yr]

c. Total operating and maintenance costs

COSTO(N,1) = 0 POS15500

COSTO = 0 [cents/1000gal]

Mechanical aeration

a. Capital cost

Function of THP

`X = ALOG(THP)` POS16600

$X = \ln \text{THP}$

For THP < 20

`CCOST(N,2) = 20000.` POS17300

CCOST = 20000 [dollars]

For THP $\geq$ 20

`CCOST(N,2) = EXP(2.848804-.223685*X+.142476*X**2.-.005985*X**3.)*1000.` POS18000

$\text{CCOST} = 1000e^{2.848804-0.223685X+0.142476X^2-0.005985X^3}$ [dollars]

b. Operating manhours, maintenance manhours, and materials/supplies costs

Function of THP/ECF_s

`X = ALOG(THP/DMATX(15,N))` POS18800

$X = \ln \frac{\text{THP}}{\text{ECF}_s}$

(*) For ($\text{THP/ECF}_s < 40$)

(**) For ($\text{THP/ECF}_s \geq 40$)

(1) Operating manhours POS19500

(*) OHRS = 600 [hrs/yr]

(**) `OHRS = EXP(6.716272-.310684*X+.112744*X**2.-.004877*X**3.)` POS20400

$\text{OHRS} = e^{6.716272-0.310684X+0.112744X^2-0.004877X^3}$ [hrs/yr]

(2) Maintenance manhours POS19600

(*) XMHRS = 300 [hrs/yr]

(**) `XMHRS = EXP(4.251092+.467681*X+.008276*X**2.)` POS 20500

$\text{XMHRS} = e^{4.251092+0.467681X+0.008276X^2}$ [hrs/yr]

(3) Blower kilowatts

`XKW = .8*THP/DMATX(15,N)` POS21000

$\text{XKW} = \frac{0.8\text{THP}}{\text{ECF}_s}$ [kilowatts]

(4) Blower kilowatt years

`XKWPY = XKW*24.*365.` POS21100

$XKWPY = 24XKW*365$ [kwhr/yr]

(5) Energy cost

`ECOST = XKWPY*DMATX(10,20)` POS21200

$ECOST = 24XKW*365*CKWH$ [$/yr]

(6) Service cost

`PCFM = THP/DMATX(15,N)/8.1/144.*(33000.*.8)/1000.` POS21300

$$PCFM = \frac{THP*33000*0.8}{8.1ECF_s*144*1000}$$ [cfm]

`SCOST = EXP(.621382+.482047*ALOG(PCFM))*1000.` POS21400

$$SCOST = 1000e^{0.621382+0.482047(\ln PCFM)}$$ [$/yr]

c. Total operating and maintenance costs POS21900

`COSTO(N,2) = ((OHRS+XMHRS)*DHR*(1.+PCT)+SCOST*WPI+ECOST)/SMATX(2,1)/3650.`

$$COSTO = \frac{(OHRS+XMHRS)DHR(1+PCT)+(SCOST*WPI)+ECOST}{Q_{Plant\ Inf.} * 3650}$$ [cents/1000 gal]

Diffused aeration

a. Capital cost

Function of CFM

`X = ALOG(CFM/1000.)` POS22700

$$X = \ln \frac{CFM}{1000}$$

(*) For $(\frac{CFM}{1000} < 1)$

(**) For $(\frac{CFM}{1000} \geq 1)$

(*) CCOST = 13000 POS23400 [dollars]

(**) `CCOST(N,2) = EXP(4.145454+.633339*X+.031939*X**2.-.002419*X**3.)*1000.`
POS24100

$$CCOST = 1000e^{4.145454+0.633339X+0.031939X^2-0.002419X^3}$$ [dollars]

b. Operating manhours, maintenance manhours and materials/supplies costs

Function of CFM/ECF$_s$

```
X = ALOG(CFM/1000./DMATX(15,N))                                    POS24900
```

$$X = \ln \frac{CFM}{1000ECF_s}$$

(*) For $\left(\frac{CFM}{1000ECF_s} < 1\right)$

(**) For $\left(\frac{CFM}{1000ECF_s} \geq 1\right)$

(1) Operating manhours POS25700

(*) OHRS = 850 [hrs/yr]

```
(**) OHRS = EXP(6.900586+.323725*X+.059093*X**2.-.004926*X**3.)    POS26600
```

$$OHRS = e^{6.900586+0.323725X+0.059093X^2-0.004926X^3}$$ [hrs/yr]

(2) Maintenance manhours POS25800

(*) XMHRS = 350 [hrs/yr]

```
(**) XMHRS = EXP(6.169937+.294853*X+.175999*X**2.-.040947*X**3.+.003300*X**4.)
```

$$XMHRS = e^{6.169937+0.294853X+0.175999X^2-0.040947X^3+0.003300X^4}$$ [hrs/yr]

POS26700

(3) Blower horsepower

```
CHP = CFM/DMATX(15,N)*8.1*144./(33000.*.8)                         POS27300
```

$$CHP = \frac{CFM*8.1*144}{ECF_s*33000*0.8}$$ [horsepower]

(4) Blower kilowatts

```
XKW = .8*CHP                                                       POS27400
```

$$XKW = \frac{CFM*8.1*144}{ECF_s*33000}$$ [kilowatts]

(5) Blower kilowatt years

```
XKWPY = XKW*24.*365.                                               POS27500
```

XKWPY = 24XKW*365 [kwhr/yr]

(6) Energy cost

```
ECOST = XKWPY*DMATX(10,20)                                         POS27600
```

ECOST = 24XKW*365CKWH [$/yr]

(7) Service cost

```
SCOST = EXP(.621382+.482047*X)*1000.                    POS27700
```

$$\mathrm{SCOST} = 1000e^{0.621382+0.482047X} \qquad [\$/\mathrm{yr}]$$

c. Total operating and maintenance costs POS28200

```
COSTO(N,2) = ((OHRS+XMHRS)*DHR*(1.+PCT)+SCOST*WPI+ECOST)/SMATX(2,1)/3650.
```

$$\mathrm{COSTO} = \frac{\mathrm{(OHRS+XMHRS)DHR(1+PCT)+(SCOST*WPI)+ECOST}}{Q_{\mathrm{Plant\ Inf.}} * 3650} \qquad [\mathrm{cents/1000\ gal}]$$

```
C                                                                       POS00100
C             POST AERATION                                             POS00200
C             PROCESS IDENTIFICATION NUMBER  19                         POS00300
C                                                                       POS00400
      SUBROUTINE POSTA                                                  POS00500
C                                                                       POS00600
C                                                                       POS00700
C             COMMON INITIAL STATEMENTS                                 POS00800
C                                                                       POS00900
      INTEGER OS1,OS2                                                   POS01000
      DIMENSION SIZE(14)                                                POS01100
      COMMON SMATX(20,30),TMATX(20,30),DMATX(20,20),OMATX(20,20),IP(20),POS01200
     1INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),ACOST(20,5)POS01300
     2,TCOST(20,5),DHR,PCT,WPI,CLAND,DLAND,FLOW(25),POW(25),TKWHD(25)   POS01400
      DATA SIZE/5.,7.5,10.,15.,20.,25.,30.,40.,50.,60.,75.,100.,125.,150POS01500
     1./                                                                POS01600
C                                                                       POS01700
C                                                                       POS01800
C             ASSIGNMENT OF DESIGN VALUES TO PROCESS PARAMETERS         POS01900
C                                                                       POS02000
      ITYPE=DMATX(1,N)                                                  POS02100
      L=DMATX(2,N)                                                      POS02200
      DOIN=DMATX(3,N)                                                   POS02300
      DOUT=DMATX(4,N)                                                   POS02400
      TL=DMATX(5,N)                                                     POS02500
      TD=DMATX(6,N)                                                     POS02600
      TW=DMATX(7,N)                                                     POS02700
      AERFO=DMATX(8,N)                                                  POS02800
      HPHRO=DMATX(9,N)                                                  POS02900
      ALT=DMATX(10,N)                                                   POS03000
      CFMDF=DMATX(11,N)                                                 POS03100
      DIFFT=DMATX(12,N)                                                 POS03200
      DD=DMATX(13,N)                                                    POS03300
C                                                                       POS03400
C                                                                       POS03500
C             EFFLUENT STREAM CALCULATIONS                              POS03600
C                                                                       POS03700
      DO 10 I=2,20                                                      POS03800
   10 SMATX(I,OS1)=SMATX(I,IS1)                                         POS03900
C                                                                       POS04000
C                                                                       POS04100
C             CALC. OF OUTPUT SIZES AND QUANTITIES                      POS04200
C                                                                       POS04300
      IF (7.5-DOUT) 20,40,40                                            POS04400
   20 WRITE (IO,30)                                                     POS04500
   30 FORMAT (////,10X,'DEMAND DOUT OF POST AERATION IS TOO HIGH',////) POS04600
   40 CAER=.024                                                         POS04700
      CY=.65                                                            POS04800
      CE=.125                                                           POS04900
      ALPHA=.9                                                          POS05000
      BETA=.95                                                          POS05100
      S=SMATX(8,IS1)+SMATX(17,IS1)                                      POS05200
      XA=OMATX(9,L)*OMATX(3,L)                                          POS05300
      CFM=0.                                                            POS05400
      HP=0.                                                             POS05500
      CFMMG=0.                                                          POS05600
      HPMG=0.                                                           POS05700
      DEPTH=0.                                                          POS05800
      TMIN=0.                                                           POS05900
      VAER=0.                                                           POS06000
      VMG=0.                                                            POS06100
      VCF=0.                                                            POS06200
      VDEL=0.                                                           POS06300
      WIDTH=0.                                                          POS06400
      AERFF=0.                                                          POS06500
      CLEN=0.                                                           POS06600
      VFM=0.                                                            POS06700
      TLEN=0.                                                           POS06800
      HP1=0.                                                            POS06900
      XN=0.                                                             POS07000
      THP=0.                                                            POS07100
      CSS=14.652-.410220*TL+.007991*TL**2.-.000078*TL**3.               POS07200
      RP=(760.-.025*ALT)/760.                                           POS07300
      CSW=RP*CSS*BETA                                                   POS07400
      IF (ITYPE) 50,140,150                                             POS07500
   50 VMG=0.                                                            POS07600
      AERK1=.31942*(CSW-DOUT)*HPHRO*ALPHA*1.025**(TL-20.)               POS07700
      AERK2=.58*CAER*XA*S/CY+1.16*CE*XA                                 POS07800
      NT=0                                                              POS07900
   60 NT=NT+1                                                           POS08000
      HP=(SMATX(2,IS1)*(DOUT-DOIN)+AERK2*VMG)/AERK1*DMATX(15,N)         POS08100
      VCF=(17.+.53*HP)**2.*(5.+.07*HP)                                  POS08200
      VMGP=VMG                                                          POS08300
      VMG=VCF*7.48/1000000.*DMATX(16,N)                                 POS08400
      VDEL=ABS(VMG-VMGP)                                                POS08500
      IF (NT-25) 90,90,70                                               POS08600
   70 WRITE (IO,80)                                                     POS08700
   80 FORMAT (////,10X,'POST AERATION ITERATION DOES NOT CONVERGE',////)POS08800
      GO TO 100                                                         POS08900
   90 IF (VDEL-.0001) 100,100,60                                        POS09000
  100 DO 120 I=1,14                                                     POS09100
      IF (HP-SIZE(I)) 110,110,120                                       POS09200
  110 HP1=SIZE(I)                                                       POS09300
      XN=1.                                                             POS09400
      GO TO 130                                                         POS09500
  120 CONTINUE                                                          POS09600
      HP1=150.                                                          POS09700
      XN=HP/150.                                                        POS09800
      IXN=XN                                                            POS09900
      XN=IXN+1                                                          POS10000
  130 THP=HP1*XN                                                        POS10100
      WIDTH=17.+.53*HP1                                                 POS10200
      DEPTH=5.+.07*HP1                                                  POS10300
      VCF=DEPTH*WIDTH**2.                                               POS10400
      VMG=(VCF*7.48/1000000.)*XN                                        POS10500
      HPMG=THP/VMG                                                      POS10600
      DAYS=VMG/SMATX(2,IS1)                                             POS10700
      TMIN=DAYS*1440.                                                   POS10800
      VAER=VMG*1000./7.48                                               POS10900
      GO TO 160                                                         POS11000
  140 CFMMG=CFMDF*DIFFT*1000000./TD/TW/7.48                             POS11100
      AERFF=AERFO*(DD/13.)**.66666*(8./CFMDF)**.2                       POS11200
      AERK1=.33547*CFMMG*AERFF*ALPHA*1.025**(TL-20.)                    POS11300
      AERK2=.58*CAER*XA*S/CY-1.16*CE*XA                                 POS11400
      TEMP=(AERK1*(CSW-DOUT)-AERK2)/(AERK1*(CSW-DOIN)-AERK2)            POS11500
      DAYS=-1.*ALOG(TEMP)/AERK1                                         POS11600
      TMIN=DAYS*1440.                                                   POS11700
      VFM=SMATX(2,IS1)*92.84/TD/TW                                      POS11800
      CLEN=VFM*TMIN                                                     POS11900
      CFM=CLEN*CFMDF*DIFFT*DMATX(15,N)                                  POS12000
      GO TO 160                                                         POS12100
  150 CFMMG=CFMDF*DIFFT*1000000./TD/TW/7.48                             POS12200
      AERFF=AERFO*(DD/13.)**.66666*(8./CFMDF)**.2                       POS12300
      AERK1=.33347*CFMMG*AERFF*ALPHA*1.025**(TL-20.)                    POS12400
      AERK2=.58*CAER*XA*S/CY-1.16*CE*XA                                 POS12500
      VMG=SMATX(2,IS1)*(DOUT-DOIN)/(AERK1*(CSW-DOUT)-AERK2)*DMATX(16,N) POS12600
      DAYS=VMG/SMATX(2,IS1)                                             POS12700
      TMIN=DAYS*1440.                                                   POS12800
      TLEN=VMG*1000000./TD/TW/7.48                                      POS12900
      VAER=VMG*1000./7.48                                               POS13000
      CFM=CFMMG*VMG*DMATX(15,N)                                         POS13100
C                                                                       POS13200
C                                                                       POS13300
C             CALC. OF CAPITAL AND OPERATING COSTS FOR POSTA BASIN      POS13400
C                                                                       POS13500
  160 IF (ITYPE) 170,180,170                                            POS13600
C                                                                       POS13700
C                                                                       POS13800
C                  CALC. OF CAPITAL COSTS FOR POSTA BASIN BASED ON      POS13900
C                  DESIGN PLUS EXCESS CAPACITY IF MECHANICAL AERATION   POS14000
C                  OR DIFFUSED AIR OF COMPLETE MIX IS USED              POS14100
C                                                                       POS14200
  170 X=ALOG(VAER)                                                      POS14300
      CCOST(N,1)=EXP(2.180040+.351346*X+.064188*X**2.-.003403*X**3.)*100POS14400
     10.                                                                POS14500
C                                                                       POS14600
C                                                                       POS14700
C                  CALC. OF OPERATING COSTS FOR POSTA BASIN BASED ON    POS14800
C                  DESIGN CAPACITY ALONE, DOES NOT INCLUDE EXCESS       POS14900
C                  CAPACITY                                             POS15000
C                                                                       POS15100
      OHRS=0.                                                           POS15200
      XMHRS=0.                                                          POS15300
      TMSU=0.                                                           POS15400
      COSTO(N,1)=0.                                                     POS15500
C                                                                       POS15600
C                                                                       POS15700
C             CALC. OF CAPITAL AND OPERATING COSTS FOR AERATION         POS15800
C                                                                       POS15900
  180 IF (ITYPE) 190,260,260                                            POS16000
C                                                                       POS16100
C                                                                       POS16200
C                  CALC. OF CAPITAL COSTS FOR MECHANICAL AERATION       POS16300
C                  SYSTEM BASED ON DESIGN PLUS EXCESS CAPACITY          POS16400
C                                                                       POS16500
  190 X=ALOG(THP)                                                       POS16600
      IF (THP-20.) 200,210,210                                          POS16700
C                                                                       POS16800
C                                                                       POS16900
C                      CALC. OF CAPITAL COSTS FOR SMALL AERATION        POS17000
C                      CAPACITY, LESS THAN 20 HP.                       POS17100
C                                                                       POS17200
  200 CCOST(N,2)=20000.                                                 POS17300
      GO TO 220                                                         POS17400
C                                                                       POS17500
C                                                                       POS17600
C                      CALC. OF CAPITAL COSTS FOR LARGE AERATION        POS17700
C                      CAPACITY, EQUAL OR GREATER THAN 20 HP.           POS17800
C                                                                       POS17900
  210 CCOST(N,2)=EXP(2.848804-.223685*X+.142476*X**2.-.005985*X**3.)*100POS18000
     10.                                                                POS18100
C                                                                       POS18200
C                                                                       POS18300
C                  CALC. OF OPERATING COSTS FOR MECHANICAL AERATION     POS18400
C                  SYSTEM BASED ON DESIGN CAPACITY ALONE, DOES NOT      POS18500
C                  INCLUDE EXCESS CAPACITY                              POS18600
C                                                                       POS18700
  220 X=ALOG(THP/DMATX(15,N))                                           POS18800
      IF (THP/DMATX(15,N)-40.) 230,240,240                              POS18900
```

```
C                                                                       POS19000
C                                                                       POS19100
C                       CALC. OF OPERATING MANHOURS AND MAINTENANCE     POS19200
C                       MANHOURS FOR AERATION CAPACITY, LESS THAN 40 HP POS19300
C                                                                       POS19400
  230 OHRS=600.                                                         POS19500
      XMHRS=300.                                                        POS19600
      GO TO 250                                                         POS19700
C                                                                       POS19800
C                                                                       POS19900
C                       CALC. OF OPERATING MANHOURS AND MAINTENANCE     POS20000
C                       MANHOURS FOR AERATION CAPACITY, EQUAL OR        POS20100
C                       GREATER THAN 40 HP.                             POS20200
C                                                                       POS20300
  240 OHRS=EXP(6.716272-.310684*X+.112744*X**2.-.004877*X**3.)          POS20400
      XMHRS=EXP(4.251092+.467681*X+.008276*X**2.)                       POS20500
C                                                                       POS20600
C                                                                       POS20700
C                       CALC. OF SUPPLIES AND ELECTRICAL POWER COSTS    POS20800
C                                                                       POS20900
  250 XKW=.8*THP/DMATX(15,N)                                            POS21000
      XKWPY=XKW*24.*365.                                                POS21100
      ECOST=XKWPY*DMATX(10,20)                                          POS21200
      PCFM=THP/DMATX(15,N)/8.1/144.*(33000.*.8)/1000.                   POS21300
      SCOST=EXP(.621382+.482047*ALOG(PCFM))*1000.                       POS21400
C                                                                       POS21500
C                                                                       POS21600
C                       OPERATING COST EQUATION                         POS21700
C                                                                       POS21800
      COSTO(N,2)=((OHRS+XMHRS)*DHR*(1.+PCT)+SCOST*WPI+ECOST)/SMATX(2,1)/POS21900
     13650.                                                             POS22000
      GO TO 330                                                         POS22100
C                                                                       POS22200
C                                                                       POS22300
C                  CALC. OF CAPITAL COSTS FOR DIFFUSED AIR AERATION     POS22400
C                  SYSTEM BASED ON DESIGN PLUS EXCESS CAPACITY          POS22500
C                                                                       POS22600
  260 X=ALOG(CFM/1000.)                                                 POS22700
      IF (CFM/1000.-.1) 270,280,280                                     POS22800
C                                                                       POS22900
C                                                                       POS23000
C                       CALC. OF CAPITAL COSTS FOR SMALL AIR            POS23100
C                       REQUIREMENT, LESS THAN 1000 CFM.                POS23200
C                                                                       POS23300
  270 CCOST(N,2)=13000.                                                 POS23400
      GO TO 290                                                         POS23500
C                                                                       POS23600
C                                                                       POS23700
C                       CALC. OF CAPITAL COSTS FOR LARGE AIR            POS23800
C                       REQUIREMENT, EQUAL OR GREATER THAN 1000 CFM.    POS23900
C                                                                       POS24000
  280 CCOST(N,2)=EXP(4.145454+.633339*X+.031939*X**2.-.002419*X**3.)*100POS24100
     10.                                                                POS24200
C                                                                       POS24300
C                                                                       POS24400
C                  CALC. OF OPERATING COSTS FOR DIFFUSED AIR AERATION   POS24500
C                  SYSTEM BASED ON DESIGN CAPACITY ALONE, DOES NOT      POS24600
C                  INCLUDE EXCESS CAPACITY                              POS24700
C                                                                       POS24800
  290 X=ALOG(CFM/1000./DMATX(15,N))                                     POS24900
      IF (CFM/1000./DMATX(15,N)-1.) 300,310,310                         POS25000
C                                                                       POS25100
C                                                                       POS25200
C                       CALC. OF OPERATING MANHOURS AND MAINTENANCE     POS25300
C                       MANHOURS FOR AIR REQUIREMENT, LESS THAN 1000    POS25400
C                       CFM.                                            POS25500
```

```
C
  300 OHRS=850.
      XMHRS=350.
      GO TO 320
C
C
C                       CALC. OF OPERATING MANHOURS AND MAINTENANCE
C                       MANHOURS FOR AIR REQUIREMENT, EQUAL OR GREATER
C                       THAN 1000 CFM.
C
  310 OHRS=EXP(6.900586+.323725*X+.059093*X**2.-.004926*X**3.)
      XMHRS=EXP(6.169937+.294853*X+.175999*X**2.-.040947*X**3.+.003300*X
     1**4.)
C
C
C                       CALC. OF SUPPLIES AND ELECTRICAL POWER COSTS
C
  320 CHP=CFM/DMATX(15,N)*8.1*144./(33000.*.8)
      XKW=.8*CHP
      XKWPY=XKW*24.*365.
      ECOST=XKWPY*DMATX(10,20)
      SCOST=EXP(.621382+.482047*X)*1000.
C
C
C                       OPERATING COST EQUATION
C
      COSTO(N,2)=((OHRS+XMHRS)*DHR*(1.+PCT)+SCOST*WPI+ECOST)/SMATX(2,1)/
     13650.
C
C
C             ASSIGNMENT OF VALUES TO OMATX
C
  330 OMATX(1,N)=VAER
      OMATX(2,N)=CFM
      OMATX(3,N)=HP
      OMATX(4,N)=TMIN
      OMATX(5,N)=VMG
      OMATX(6,N)=AERFF
      OMATX(8,N)=HP1
      OMATX(9,N)=XN
      OMATX(10,N)=THP
      OMATX(11,N)=WIDTH
      OMATX(12,N)=DEPTH
      OMATX(13,N)=TLEN
C
C
C             PROCESS ENERGY INDICES
C
      FLOW(N)=SMATX(2,IS1)
      POW(N)=19.
      RETURN
      END
```

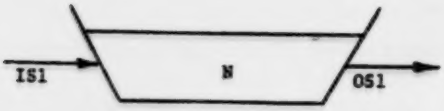
SECTION 21

EQUALIZATION, EQUAL

Subroutine Identification Number 20

Equalization, EQUAL Rev. Date 8/1/77

1. Process symbol.



IS1: Liquid input stream

OS1: Liquid output stream

N: User assigned number to the process

2. Input parameters and nominal values.

DMATX(1,N) = IAER	Program control: 0 = Small impeller mechanical aerators on floating platforms are used, 1 = large impeller mechanical aerators on stationary platforms are used. [1.]
DMATX(2,N) = RLW	Ratio of length to width for the equalization basin. [1.]
DMATX(3,N) = COSTL	Cost of pond lining material, $/sq ft. [.5]
DMATX(4,N) = HEAD	Pumping head of effluent pumps from the equalization basin, ft. [10.]
DMATX(5,N) = IMAT	Program control: 0 = Earthen pond with mechanical aeration is used for the equalization basin, 1 = concrete tank with diffused air is used for the equalization basin. [0.]
DMATX(14,N) = ECF	Excess capacity factor for the pumping system. [1.25]
DMATX(15,) = ECF	Excess capacity factor for the surface aerators. [1.]
DMATX(16,N) = ECF	Excess capacity factor for the equalization basin. [1.]

3. Output parameters which are printed on computer output sheets.

IAER = DMATX(1,N)

RLW = DMATX(2,N)

COSTL = DMATX(3,N)

HEAD = DMATX(4,N)

IMAT = DMATX(5,N)	
WIDTH = OMATX(1,N)	Equalization basin width at the water line, ft.
AREA = OMATX(2,N)	Equalization basin area at the water surface, acres.
VUMG = OMATX(3,N)	Usable liquid volume of the equalization basin, mg.
VOMG = OMATX(4,N)	Minimum liquid volume of the equalization basin, mg.
VT = OMATX(5,N)	Total liquid volume of the equalization basin (VUMG + VOMG), mg.
SAREA = OMATX(6,N)	Area of the lining required for the equalization basin, sq ft.
HP = OMATX(7,N)	Mechanical aerator brake horsepower, hp.
HP1 = OMATX(8,N)	Brake horsepower (HP) rounded off to the next higher available size mechanical aerator, hp.
XN = OMATX(9,N)	Number of mechanical aerators required.
THP = OMATX(10,N)	Total mechanical aeration brake horsepower required (HP1*XN),hp.
PLAND = OMATX(11,N)	Amount of land needed for the equalization basin (this land area requirement is included in the total land area requirement, ACRE, for the whole plant), acres.
CLAND = OMATX(12,N)	Cost of land needed for the equalization basin (this cost is included in the total plant cost, XLAND, for land), $.
VAER = OMATX(13,N)	Volume of the concrete tank used for the equalization basin, cu ft/1000.
ECFM = OMATX(14,N)	Required size of the blower for supplying air to the concrete equalization basin, cfm.
CCOST	Capital cost,[dollars].
COSTO	Operating and maintenance cost,[cents/1000gal].
ACOST	Amortization cost,[cents/1000 gal].
TCOST	Total treatment cost,[cents/1000 gal].
ECF	Excess capacity factor.

4. **Theory and functions - FORTRAN statement followed by equivalent algebraic equation.**

```
QP = 1.78*SMATX(2,IS1)**.92                                        EQU04400
```

$$QP = 1.78[Q_{IS1}]^{0.92} \qquad [MGD]$$

```
VU = SMATX(2,IS1)*.12*1000000./7.48*DMATX(16,N)                    EQU04500
```

$$VU = \frac{Q_{IS1}*0.12*1000000*ECF}{7.48} \qquad [ft^3]$$

```
SAREA = (2.*WIDTH*(1.+RLW)-156.)*53.76+(WIDTH-90.)*(RLW*WIDTH-90.)+20.*(24.+
        (1.+RLW)*WIDTH)
                                                                   EQU05200
```

$$SAREA = (2WIDTH(1+RLW)-156)*53.76+(WIDTH-90)(RLW*WIDTH-90)+20(24+(1+RLW)WIDTH) \qquad [ft^2]$$

```
WIDTH = (300.*(1.+RLW)+(90000.*(1.+RLW)**2.-40.*RLW*(12000.-VU))**.5)/20./RLW
```

$$WIDTH = \frac{300(1+RLW)+[90000(1+RLW)^2-40RLW(12000-VU)]^{0.5}}{20RLW} \qquad [ft] \qquad \text{EQU05500}$$

```
AREA = RLW*WIDTH**2./43560.
                                                                   EQU05700
```

$$AREA = \frac{RLW(WIDTH)^2}{43560} \qquad [acre]$$

```
VMIN = 5.*RLW*WIDTH**2.-375.*WIDTH*(1.+RLW)+28500.                 EQU05800
```

$$VMIN = 5RLW(WIDTH)^2-375WIDTH(1+RLW)+28500$$

```
SAREA = (2.*WIDTH*(1.+RLW)-156.)*53.76+(WIDTH-90.)*(RLW*WIDTH-90)+20.*(24.+
        (1.+RLW)*WIDTH)
                                                                   EQU05900
```

$$SAREA = (2WIDTH(1+RLW)-156)53.76+(WIDTH-90)(RLW*WIDTH-90)+20(24+(1+RLW)WIDTH) \qquad [ft^2]$$

```
WIDTH = (300.*(1.+RLW)+(90000.*(1.+RLW)**2.-40.*RLW*(12000.-VU))**.5)/20./RLW
                                                                   EQU06200
```

$$WIDTH = \frac{300(1+RLW)+[90000(1+RLW)^2-40RLW(12000-VU)]^{0.5}}{20RLW} \qquad [ft]$$

`AREA = RLW*WIDTH**2./43560.` EQU06400

$$AREA = \frac{RLW(WIDTH)^{2}}{43560} \qquad \text{[acre]}$$

`VMIN = VU*.2857` EQU06500

$$VMIN = 0.2857VU \qquad [ft^{3}]$$

`VUMG = VU*7.48/1000000.` EQU06700

$$VUMG = \frac{7.48VU}{1000000} \qquad \text{[MG]}$$

`VOMG = VMIN*7.48/1000000.` EQU06800

$$VOMG = \frac{7.48VMIN}{1000000} \qquad \text{[MG]}$$

`VT = VUMG+VOMG` EQU06900

$$VT = \frac{7.48(VU+VMIN)}{1000000} \qquad \text{[MG]}$$

`HPA = VT*29.88 (For VT>1.4)` EQU07200

$$HPA = 29.88VT \qquad \text{[horsepower]}$$

`HPA = VT*35.36/(VT**.5)  (For VT≤1.4)` EQU07400

$$HPA = \frac{35.36VT}{(VT)^{0.5}} \qquad \text{[horsepower]}$$

`HPB = VT*59./(VT**.4254)` EQU07500

$$HPB = \frac{59VT}{(VT)^{0.4254}} \qquad \text{[horsepower]}$$

`HP = HPB*DMATX(15,N)  (For HPA<HPB)` EQU07700

$$HP = HPB*ECF \qquad \text{[horsepower]}$$

HP = HPA*DMATX(15,N) (For $HPA \geq HPB$) EQU07900

HP = HPA*ECF [horsepower]

HP1 = SIZE(I) EQU08200

HP1 = SIZE(I) [horsepower]

where I = 1,14

Pump efficiency - Current values used in program; each can be changed by the replacement on punched card.

PEFF = 0.70 for $Q_{IS1} < 1.44$MGD EQU11500

PEFF = 0.74 for $Q_{IS1} < 10.08$MGD EQU11800

PEFF = 0.83 for $Q_{IS1} \geq 10.08$MGD EQU12000

VAER = VT*1000./7.48 EQU15000

$$VAER = \frac{1000VT}{7.48} \quad [ft^3/1000]$$

ECFM = 20.*VAER*DMATX(15,N) [ft^3/min] EQU17000

ECFM = 20VAER*ECF

SMATX(I,OS1) = SMATX(I,IS1)

SMATX(I,OS1) = SMATX(I,IS1) [mg/1]

where I = 2.20 i.e. Q,SOC,SNBC,SON,SOP,SFM,SBOD,VSS,TSS,DOC,DNBC,DN,DP,DFM, ALK,DBOD,NH3,NO3

References:

Patterson and Banker, 1971

Smith Eilers Hall Feb 1973

5. **Cost functions.**

Equal basin

a. **Capital cost**

Function of VAER

`X = ALOG(VAER)` EQU15600

$X = \ln VAER$

`CCOST(N,1) = EXP(2.414380+.175682*X+.084742*X**2.-.002670*X**3.)*1000.`

EQU15700

$CCOST = 1000e^{2.414380+0.175682X+0.084742X^2-0.002670X^3}$ [dollars]

b. **Total operating and maintenance costs** EQU16400

`COSTO(N,1) = 0` [cents/1000gal]

Blower

a. **Capital cost**

Function of ECFM

`X = ALOG(ECFM/1000.)` EQU17100

$X = \ln \frac{ECFM}{1000}$

`CCOST(N,2) = EXP(4.145454+.633339*X+.031939*X**2.-.002419*X**3.)*1000.`

EQU17200

$CCOST = 1000e^{4.145454+0.633339X+0.031939X^2-0.002419X^3}$ [dollars]

b. **Operating manhours, maintenance manhours, and materials/supplies costs**

Function of ECFM/ECF

`X = ALOG(ECFM/1000./DMATX(15,N))` EQU17900

$X = \ln \frac{ECFM}{1000ECF}$

(1) Operating manhours

`OHRS = EXP(6.900586+.323725*X+.059093*X**2.-.004926*X**3.)` EQU18500

$OHRS = e^{6.900586+0.323725X+0.059093X^2-0.004926X^3}$ [hrs/yr]

(2) Maintenance manhours EQU18600

XMHRS = EXP(6.169937+.294853*X+.175999*X**2.-.04097*X** 3.+.003300*X**4.)

$$XHHRS = e^{6.169937+0.294853X+0.175999X^{2}-0.040947X^{3}+0.003300X^{4}} \quad [hrs/yr]$$

(3) Blower horsepower

EHP = ECFM/DMATX(15,N)*8.1*144./(33000.*.8) EQU18800

$$EHP = \frac{8.1ECFM*144}{33000ECF*0.8} \quad [hp]$$

(4) Blower kilowatts

XKW = .8*EHP EQU18900

$$XKW = \frac{8.1ECFM*144}{33000ECF} \quad [kw]$$

(5) Blower kilowatt years

XKWPY = XKW*24.*365. EQU19000

$$XKWPY = 24XKW*365 \quad [kw\text{-}yrs]$$

(6) Energy cost

ECOST = XKWPY*DMATX(10,20) EQU19100

$$ECOST = 24XKW*365*CKWH \quad [dollars/yr]$$

(7) Supplies cost

SCOST = EXP(.621382+.482047*X)*1000. EQU19200

$$SCOST = 1000e^{0.621382+0.482047X} \quad [dollars/yr]$$

c. Total operating and maintenance costs EQU19700

COSTO(N,2) = ((OHRS+XMHRS)*DHR*(1.+PCT)+SCOST*WPI+ECOST)/SMATX(2,1)/3650.

$$COSTO = \frac{[(OHRS+XMHRS)*DHR*(1+PCT)]+(SCOST*WPI)+ECOST}{Q_{Plant\ inf.}*3650} \quad [cents/1000gal]$$

Pumping system of concrete tank

a. **Capital cost**

Function of $Q_{IS1}*ECF$

```
X = ALOG(SMATX(2,IS1)*DMATX(14,N))                                  EQU09600
```

$$X = \ln (Q_{IS1}*ECF)$$

```
CCOST(N,3) = EXP(3.481553+.377485*X+.093349*X**2.-.006222*X**3.)*1000.
                                                                    EQU09700
```

$$CCOST = 1000e^{3.481553+0.377485X+0.093349X^2-0.006222X^3} \quad [\text{dollars}]$$

b. **Operating manhours, maintenance manhours and materials/supplies costs**

Function of Q_{IS1}

```
X = ALOG(SMATX(2,IS1))                                              EQU10500
```

$$X = \ln Q_{IS1}$$

(1) **Operating manhours** EQU11100

```
OHRS = EXP(6.097269+.253066*X-.193659*X**2.+.078201*X**3.-.006680*X**4.)
```

$$OHRS = e^{6.097269+0.253066X-0.193659X^2+0.078201X^3-0.006680X^4} \quad [\text{hrs/yr}]$$

(2) **Maintenance manhours**

```
XMHRS = EXP(5.911541-.013158*X+.076643*X**2.)                       EQU11300
```

$$XMHRS = e^{5.911541-0.013158X+0.076643X^2} \quad [\text{hrs/yr}]$$

(3) **Kilowatt hrs per year** EQU12100

```
YRKW = SMATX(2,IS1)*1000000.*HEAD/1440./3960./PEFF/.9*.7457*24.*365.
```

$$YRKW = \frac{Q_{IS1}*1000000*HEAD*0.7457*24*365}{1440*3960*PEFF*0.9} \quad [\text{kwhr/yr}]$$

(4) **Energy cost**

```
ECOST = YRKW*DMATX(10,20)                                           EQU12200
```

$$ECOST = YRKW*CKWH \quad [\text{dollars/yr}]$$

(5) Supplies cost

SCOST = EXP(5.851743+.301610*X+.197183*X**2.-.017962*X**3.) EQU12300

$$SCOST = e^{5.851743+0.301610X+0.197183X^2-0.017962X^3}$$ [dollars/yr]

(6) Total materials and supplies

TMSU = ECOST+SCOST*WPI EQU12400

$$TMSU = ECOST+(SCOST*WPI)$$ [dollars/yr]

c. Total operating and maintenance costs

COSTO(N,3) = (COHRS+XMHRS)*DHR*(1.+PCT)+TMSU)/SMATX(2,1)/3650. EQU12900

$$COSTO = \frac{[(OHRS+XMHRS)*DHR*(1+PCT)]+TMSU}{Q_{Plant\ Inf.}*3650}$$ [cents/1000gal]

Pumping system of earthen pond

a. Capital cost

Function of $Q_{IS1}*ECF$

X = ALOG(SMATX(2,IS1)*DMATX(14,N)) EQU13500

$$X = \ln(Q_{IS1}*ECF)$$

CCOST(N,4) = EXP(8.109253+.646743*X) EQU13600

$$CCOST = e^{8.109253+0.646743X}$$ [dollars]

b. Total operating and maintenance costs EQU14200

COSTO(N,4) = 0 [cents/1000gal]

Equal basin for earthen pond

a. Capital cost

Function of AREA

`X = ALOG(AREA)` EQU20400

$X = \ln AREA$

(1) For AREA<1 ACRE EQU21100

`CCOST(N,1) = 22000` [dollars]

(2) For AREA$\geq$1 ACRE EQU22500

`CCOST(N,1) = EXP(3.501091+.422086*X+.079097*X**2.-.008338*X**3.)*1000.`

$CCOST = 1000e^{3.501091+0.422086X+0.079097X^2-0.008338X^3}$ [dollars]

b. Operating manhours, maintenance manhours and materials/supplies costs

(1) For AREA<1 ACRE

(a) Operating manhours EQU21700

`OHRS = 600` [hrs/yr]

(b) Maintenance manhours EQU21800

`XMHRS = 100` [hrs/yr]

(c) Total materials and supplies EQU23900

`TMSU = 0` [dollars/yr]

(2) For AREA$\geq$1 ACRE

(a) Operating manhours EQU23200

`OHRS = EXP(6.547042+.262634*X+.058298*X**2.-.013454*X**3.+.001494*X**4.)`

$OHRS = e^{6.547042+0.262634X+0.058298X^2-0.013454X^3+0.001494X^4}$ [hrs/yr]

(b) Maintenance manhours

XMHRS = EXP(4.844423+.327982*X+.017677*X**2.) EQU23400

$$XMHRS = e^{4.844423+0.327982X+0.017677X^2} \quad [hrs/yr]$$

(c) Total materials and supplies EQU23900

$$TMSU = 0 \quad [dollars/yr]$$

c. Total operating and maintenance costs EQU24400

COSTO(N,1) = ((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.

$$COSTO = \frac{(OHRS+XMHRS)*DHR*(1+PCT)+(TMSU*WPI)}{Q_{Plant\ Inf.}*3650} \quad [cents/1000gal]$$

Blower for earthen pond

a. Capital cost

Function of THP

X = ALOG(THP) EQU25000

$$X = \ln THP$$

(1) For IAER = 0 EQU25800

CCOST(N,2) = EXP(.647120+.438812*X+.031192*X**2.)*1000.

$$CCOST = 1000e^{0.647120+0.438812X+0.031192X^2} \quad [dollars]$$

(2) For IAER<>0 EQU26600

CCOST(N,2) = EXP(3.141014-.218751*X+.136739*X**2.-.006042*X**3.)*1000.

$$CCOST = 1000e^{3.141014-0.218751X+0.136739X^2-0.006042X^3} \quad [dollars]$$

b. Operating manhours, maintenance manhours and materials/supplies costs

Function of THP/ECF

X = ALOG(THP/DMATX(15,N)) EQU27300

$$X = \ln \frac{THP}{ECF}$$

(1) Operating manhours EQU27900

OHRS = 0 [hrs/yr]

(2) Maintenance manhours EQU28000

XMHRS = 0 [hrs/yr]

(3) Blower kilowatts

XKW = .8*THP/DMATX(15,N) EQU28100

$$XKW = \frac{0.8THP}{ECF}$$ [kw]

(4) Blower kilowatt years

XKWPY = XKW*24.*365. EQU28200

$$XKWPY = 24XKW*365$$ [kw/yrs]

(5) Energy cost

ECOST = XKWPY*DMATX(10,20) EQU28300

$$ECOST = 24XKW*365*CKWH$$ [dollars/yr]

(6) Supplies cost

SCOST = EXP(4.016957+.534211*X) EQU28400

$$SCOST = e^{4.016957+0.534211X}$$ [dollars/yr]

c. Total operating and maintenance costs EQU28900

COSTO(N,2) = ((OHRS+XMHRS)*DHR*(1.+PCT)+SCOST*WPI+ECOST)/SMATX(2,1)/3650.

$$COSTO = \frac{(OHRS+XMHRS)*DHR*(1+PCT)+(SCOST*WPI)+ECOST}{Q_{Plant\ Inf.}*3650}$$ [cents/1000gal]

Pond lining

a. Capital cost

CCOST(N,5) = SAREA*COSTL   EQU29500   [dollars]

b. Total operating and maintenance costs

COSTO(N,5) = 0   EQU30000   [cents/1000gal]

Land requirement

Function of AREA

X = ALOG(AREA)   EQU30500

$$X = \ln AREA$$

PLAND = EXP(1.588306+.529246*X+.038611*X**2.)   EQU30600

$$PLAND = e^{1.588306+0.529246X+0.038611X^2}$$

[acres]

CLAND = PLAND*DMATX(7,20)   EQU30700

$$CLAND = DA*e^{1.588306+0.529246X+0.038611X^2}$$

[dollars]

```
C
C             EQUALIZATION
C             PROCESS IDENTIFICATION NUMBER  20
C
      SUBROUTINE EQUAL
C
C
C             COMMON INITIAL STATEMENTS
C
      INTEGER OS1,OS2
      DIMENSION SIZE(14)
      COMMON SMATX(20,30),TMATX(20,30),DMATX(20,20),OMATX(20,20),IP(20),
     1INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),ACOST(20,5)
     2,TCOST(20,5),DHR,PCT,WPI,CLAND,DLAND,FLOW(25),POW(25),TKWHD(25)
      DATA SIZE/5.,7.5,10.,15.,20.,25.,30.,40.,50.,60.,75.,100.,125.,150
     1./
C
C
C             ASSIGNMENT OF DESIGN VALUES TO PROCESS PARAMETERS
C
      VAER=0.
      ECFM=0.
      PLAND=0.
      CLAND=0.
      HP=0.
      HP1=0.
      XN=0.
      THP=0.
      IAER=DMATX(1,N)
      RLW=DMATX(2,N)
      COSTL=DMATX(3,N)
      HEAD=DMATX(4,N)
      IMAT=DMATX(5,N)
C
C
C             EFFLUENT STREAM CALCULATIONS
C
      DO 10 I=2,20
   10 SMATX(I,OS1)=SMATX(I,IS1)
C
C
C             CALC. OF OUTPUT SIZES AND QUANTITIES
C
      QP=1.78*SMATX(2,IS1)**.92
      VU=SMATX(2,IS1)*.12*1000000./7.48*DMATX(16,N)
      IF (IMAT) 50,20,50
   20 IF (VU-39000.) 30,30,40
   30 VU=39000.
      WIDTH=90.
      AREA=.18595
      VMIN=1500.
      SAREA=(2.*WIDTH*(1.+RLW)-156.)*53.76+(WIDTH-90.)*(RLW*WIDTH-90.)+2
     10.*(24.+(1.+RLW)*WIDTH)
      GO TO 60
   40 WIDTH=(300.*(1.+RLW)+(90000.*(1.+RLW)**2.-40.*RLW*(12000.-VU))**.5
     1)/20./RLW
      AREA=RLW*WIDTH**2./43560.
      VMIN=5.*RLW*WIDTH**2.-375.*WIDTH*(1.+RLW)+26500.
      SAREA=(2.*WIDTH*(1.+RLW)-156.)*53.76+(WIDTH-90.)*(RLW*WIDTH-90.)+2EQU05900
     10.*(24.+(1.+RLW)*WIDTH)                                           EQU06000
      GO TO 60                                                          EQU06100
   50 WIDTH=(300.*(1.+RLW)+(90000.*(1.+RLW)**2.-40.*RLW*(12000.-VU))**.5EQU06200
     1)/20./RLW                                                         EQU06300
      AREA=RLW*WIDTH**2./43560.                                         EQU06400
      VMIN=VU*.2857                                                     EQU06500
      SAREA=0.                                                          EQU06600
   60 VUMG=VU*7.48/1000000.                                             EQU06700
      VOMG=VMIN*7.48/1000000.                                           EQU06800
      VT=VUMG+VOMG                                                      EQU06900
      IF (IMAT) 170,70,170                                              EQU07000
   70 IF (VT-1.4) 90,90,80                                              EQU07100
   80 HPA=VT*29.88                                                      EQU07200
      GO TO 100                                                         EQU07300
   90 HPA=VT*35.36/(VT**.5)                                             EQU07400
  100 HPB=VT*59./(VT**.4254)                                            EQU07500
      IF (HPA-HPB) 110,120,120                                          EQU07600
  110 HP=HPB*DMATX(15,N)                                                EQU07700
      GO TO 130                                                         EQU07800
  120 HP=HPA*DMATX(15,N)                                                EQU07900
  130 DO 150 I=1,14                                                     EQU08000
      IF (HP-SIZE(I)) 140,140,150                                       EQU08100
  140 HP1=SIZE(I)                                                       EQU08200
      XN=1                                                              EQU08300
      GO TO 160                                                         EQU08400
  150 CONTINUE                                                          EQU08500
      HP1=150.                                                          EQU08600
      XN=HP/150.                                                        EQU08700
      IXN=XN                                                            EQU08800
      XN=IXN+1                                                          EQU08900
  160 THP=HP1*XN                                                        EQU09000
C                                                                       EQU09100
C                                                                       EQU09200
C              CALC. OF CAPITAL COSTS FOR PUMPING SYSTEM OF CONCRETE    EQU09300
C              TANK BASED ON DESIGN PLUS EXCESS CAPACITY                EQU09400
C                                                                       EQU09500
  170 X=ALOG(SMATX(2,IS1)*DMATX(14,N))                                  EQU09600
      CCOST(N,3)=EXP(3.481553+.377485*X+.093349*X**2.-.006222*X**3.)*100EQU09700
     10.                                                                EQU09800
C                                                                       EQU09900
C                                                                       EQU10000
C              CALC. OF OPERATING COSTS FOR PUMPING SYSTEM OF CONCRETE  EQU10100
C              TANK BASED ON DESIGN CAPACITY ALONE, DOES NOT INCLUDE    EQU10200
C              EXCESS CAPACITY                                          EQU10300
C                                                                       EQU10400
      X=ALOG(SMATX(2,IS1))                                              EQU10500
C                                                                       EQU10600
C                                                                       EQU10700
C                    CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS  EQU10800
C                    AND MATERIALS AND SUPPLIES                         EQU10900
C                                                                       EQU11000
      OHRS=EXP(6.097269+.253066*X-.193659*X**2.+.078201*X**3.-.006680*X*EQU11100
     1*4.)                                                              EQU11200
      XMHRS=EXP(5.911541-.013158*X+.076643*X**2.)                       EQU11300
      IF (SMATX(2,IS1)-1.44) 180,190,190                                EQU11400
  180 PEFF=.70                                                          EQU11500
      GO TO 220                                                         EQU11600
  190 IF (SMATX(2,IS1)-10.08) 200,210,210                               EQU11700
  200 PEFF=.74                                                          EQU11800
      GO TO 220                                                         EQU11900
  210 PEFF=.83                                                          EQU12000
  220 YRKW=SMATX(2,IS1)*1000000.*HEAD/1440./3960./PEFF/.9*.7457*24.*365.EQU12100
      ECOST=YRKW*DMATX(10,20)                                           EQU12200
      SCOST=EXP(5.851743+.301610*X+.197183*X**2.-.017962*X**3.)         EQU12300
      TMSU=ECOST+SCOST*WPI                                              EQU12400
```

```
C                                                                       EQU12500
C                                                                       EQU12600
C                  OPERATING COST EQUATION                              EQU12700
C                                                                       EQU12800
      COSTO(N,3)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU)/SMATX(2,1)/3650.      EQU12900
C                                                                       EQU13000
C                                                                       EQU13100
C             CALC. OF CAPITAL COSTS FOR PUMPING SYSTEM OF EARTHEN      EQU13200
C             POND BASED ON DESIGN PLUS EXCESS CAPACITY                 EQU13300
C                                                                       EQU13400
      X=ALOG(SMATX(2,IS1)*DMATX(14,N))                                  EQU13500
      CCOST(N,4)=EXP(8.109253+.646743*X)                                EQU13600
C                                                                       EQU13700
C                                                                       EQU13800
C             CALC. OF OPERATING COSTS FOR PUMPING SYSTEM OF EARTHEN    EQU13900
C             POND                                                      EQU14000
C                                                                       EQU14100
      COSTO(N,4)=0.                                                     EQU14200
C                                                                       EQU14300
C                                                                       EQU14400
C             CALC. OF CAPITAL AND OPERATING COSTS FOR CONCRETE TANK    EQU14500
C                                                                       EQU14600
      IF (IMAT) 230,240,230                                             EQU14700
  230 VOMG=0.                                                           EQU14800
      VT=VOMG                                                           EQU14900
      VAER=VT*1000./7.48                                                EQU15000
C                                                                       EQU15100
C                                                                       EQU15200
C                  CALC. OF CAPITAL COSTS FOR EQUAL BASIN BASED ON      EQU15300
C                  DESIGN PLUS EXCESS CAPACITY                          EQU15400
C                                                                       EQU15500
      X=ALOG(VAER)                                                      EQU15600
      CCOST(N,1)=EXP(2.414360+.175682*X+.084742*X**2.-.002670*X**3.)*100EQU15700
     10.                                                                EQU15800
C                                                                       EQU15900
C                                                                       EQU16000
C                  CALC. OF OPERATING COSTS FOR EQUAL BASIN             EQU16100
C                                                                       EQU16200
C                                                                       EQU16300
      COSTO(N,1)=0.                                                     EQU16400
C                                                                       EQU16500
C                                                                       EQU16600
C                  CALC. OF CAPITAL COSTS FOR BLOWER BASED ON DESIGN    EQU16700
C                  PLUS EXCESS CAPACITY                                 EQU16800
C                                                                       EQU16900
      ECFM=20.*VAER*DMATX(15,N)                                         EQU17000
      X=ALOG(ECFM/1000.)                                                EQU17100
      CCOST(N,2)=EXP(4.145454+.633339*X+.031939*X**2.-.002419*X**3.)*100EQU17200
     10.                                                                EQU17300
C                                                                       EQU17400
C                                                                       EQU17500
C                  CALC. OF OPERATING COSTS FOR BLOWER BASED ON DESIGN  EQU17600
C                  CAPACITY ALONE, DOES NOT INCLUDE EXCESS CAPACITY     EQU17700
C                                                                       EQU17800
      X=ALOG(ECFM/1000./DMATX(15,N))                                    EQU17900
C                                                                       EQU18000
C                                                                       EQU18100
C                       CALC. OF OPERATING MANHOURS, MAINTENANCE        EQU18200
C                       MANHOURS AND ELECTRICAL POWER AND SUPPLY COSTS  EQU18300
C                                                                       EQU18400
      OHRS=EXP(6.900586+.323725*X+.059093*X**2.-.004926*X**3.)          EQU18500
      XMHRS=EXP(6.169937+.294853*X+.175999*X**2.-.040947*X**3.+.003300*XEQU18600
     1**4.)                                                             EQU18700
```

```
      EHP=ECFM/DMATX(15,N)*6.1*144./(33000.*.8)
      XKW=.8*EHP
      XKWPY=XKW*24.*365.
      ECOST=XKWPY*DMATX(10,20)
      SCOST=EXP(.621382+.482047*X)*1000.
C
C
C                       OPERATING COST EQUATION
C
      COSTO(N,2)=((OHRS+XMHRS)*DHR*(1.+PCT)+SCOST*WPI+ECOST)/SMATX(2,1)/
     13650.
      GO TO 310
C
C
C               CALC. OF CAPITAL AND OPERATING COSTS FOR EARTHEN POND
C
  240 X=ALOG(AREA)
      IF (AREA-1.) 250,260,260
C
C
C                    CALC. OF CAPITAL COSTS FOR EQUAL BASIN, LESS THAN
C                    1 ACRE
C
  250 CCOST(N,1)=22000.
C
C
C                    CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS
C                    FOR EQUAL BASIN, LESS THAN 1 ACRE
C
      OHRS=600.
      XMHRS=100.
      GO TO 270
C
C
C                    CALC. OF CAPITAL COSTS FOR EQUAL BASIN, EQUAL OR
C                    GREATER THAN 1 ACRE
C
  260 CCOST(N,1)=EXP(3.501091+.422086*X+.079097*X**2.-.008338*X**3.)*100
     10.
C
C
C                    CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS
C                    FOR EQUAL BASIN, EQUAL OR GREATER THAN 1 ACRE
C
      OHRS=EXP(6.547042+.262634*X+.058298*X**2.-.013454*X**3.+.001494*X*
     1*4.)
      XMHRS=EXP(4.844423+.327982*X+.017677*X**2.)
C
C
C                    CALC. OF SUPPLIES AND MATERIALS FOR EQUAL BASIN
C
  270 TMSU=0.
C
C
C                    OPERATING COST EQUATION FOR EQUAL BASIN
C
      COSTO(N,1)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.
C
C
C                    CALC. OF CAPITAL COSTS FOR BLOWER BASED ON DESIGN
C                    PLUS EXCESS CAPACITY
C
      X=ALOG(THP)
      IF (IAER) 290,280,290
C
C
```

```
C                       CALC. OF CAPITAL COSTS FOR BLOWER IF SMALL
C                       IMPELLER MECHANICAL AERATORS ON FLOATING
C                       PLATFORMS ARE USED
C
  280 CCOST(N,2)=EXP(.647120+.438812*X+.031192*X**2.)*1000.
      GO TO 300
C
C
C                       CALC. OF CAPITAL COSTS FOR BLOWER IF LARGE
C                       IMPELLER MECHANICAL AERATORS ON STATIONARY
C                       PLATFORMS ARE USED
C
  290 CCOST(N,2)=EXP(3.141014-.218751*X+.136739*X**2.-.006042*X**3.)*100
     10.
C
C
C                  CALC. OF OPERATING COSTS FOR BLOWER BASED ON DESIGN
C                  CAPACITY ALONE, DOES NOT INCLUDE EXCESS CAPACITY
C
  300 X=ALOG(THP/DMATX(15,N))
C
C
C                       CALC. OF OPERATING MANHOURS, MAINTENANCE
C                       MANHOURS AND ELECTRICAL POWER AND SUPPLY COSTS
C
      OHRS=0.
      XMHRS=0.
      XKW=.6*THP/DMATX(15,N)
      XKWPY=XKW*24.*365.
      ECOST=XKWPY*DMATX(10,20)
      SCOST=EXP(4.016957+.534211*X)
C
C
C                       OPERATING COST EQUATION
C
      COSTO(N,2)=((OHRS+XMHRS)*DHR*(1.+PCT)+SCOST*WPI+ECOST)/SMATX(2,1)/
     13650.
C
C
C             CALC. OF CAPITAL COSTS FOR POND LINING
C
      CCOST(N,5)=SAREA*COSTL
C
C
C             CALC. OF OPERATING COSTS FOR POND LINING
C
      COSTO(N,5)=0.
C
C
C             CALC. OF COST FOR LAND
C
      X=ALOG(AREA)
      PLAND=EXP(1.588306+.529246*X+.038611*X**2.)
      CLAND=PLAND*DMATX(7,20)
C
C
C             ASSIGNMENT OF VALUES TO OMATX
C
  310 OMATX(1,N)=WIDTH
      OMATX(2,N)=AREA
      OMATX(3,N)=VOMG
      OMATX(4,N)=VOMG
      OMATX(5,N)=VT
      OMATX(6,N)=SAREA
      OMATX(7,N)=HP
      OMATX(8,N)=HP1                                                    EQU31900
      OMATX(9,N)=XN                                                     EQU32000
      OMATX(10,N)=THP                                                   EQU32100
      OMATX(11,N)=PLAND                                                 EQU32200
      OMATX(12,N)=CLAND                                                 EQU32300
      OMATX(13,N)=VAER                                                  EQU32400
      OMATX(14,N)=ECFM                                                  EQU32500
C                                                                       EQU32600
C                                                                       EQU32700
C             PROCESS ENERGY INDICES                                    EQU32800
C                                                                       EQU32900
      FLOW(N)=SMATX(2,IS1)                                              EQU33000
      POW(N)=20.                                                        EQU33100
      RETURN                                                            EQU33200
      END                                                               EQU33300
```

SECTION 22

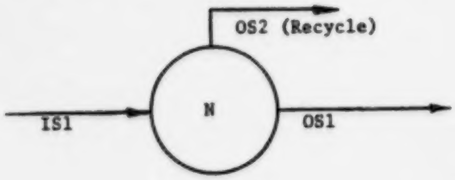
SECOND STAGE ANAEROBIC DIGESTION, DIG2

Subroutine Identification Number 21

Rev. Date 8/1/77

Second Stage Anaerobic Digestion, DIG2

1. Process symbol.



IS1: Sludge input stream

OS1: Sludge output stream

OS2: Supernatant output stream

N: User assigned number to the process

2. Input parameters and nominal values.

DMATX(1,N) = TRR	Solids recovery ratio for the second stage anaerobic digestion, [.81].
DMATX(2,N) = TSS	Total suspended solids concentration of OS1, mg/l, [50,000.].
DMATX(3,N) = TD	Second stage anaerobic digester detention time, days, [15.].
DMATX(16,N) = ECF	Excess capacity factor for the process, [1.].

3. Output parameters which are printed on computer output sheets.

TRR = DMATX(1,N)	
TSS = DMATX(2,N)	
TD = DMATX(3,N)	
VDIG = OMATX(1,N)	Volume of the second stage anaerobic digester, cu. ft./1000.
CCOST	Capital cost, [dollars].
COSTO	Operating and maintenance cost, [cents/1000 gal].
ACOST	Amortization cost, [cents/1000 gal].
TCOST	Total treatment cost, [cents/1000 gal].
ECF	Excess capacity factor.

4. Theory and functions - FORTRAN statement followed by equivalent algebraic equation.

```
VDIG = DMATX(3,N)*SMATX(2,IS1)*133.69*DMATX(16,N)                    DI204100
```

$$VDIG = TD*Q_{IS1}*133.69*ECF \quad [ft^3/1000]$$

```
SMATX(10,OS2) = ((1.-DMATX(1,N))/(1.-DMATX(1,N)*SMATX(10,IS1)/DMATX(2,N)))*SMATX(10,IS1)
```

$$TSS_{OS2} = \frac{(1-TRR)*TSS_{IS1}}{1-\frac{TRR*TSS_{IS1}}{TSS}} \quad [mg/l]$$

DI201900

```
TEMP1 = DMATX(2,N)/SMATX(10,IS1)                                     DI202100
```

$$TEMP1 = \frac{TSS}{TSS_{IS1}} \quad [\text{no units}]$$

```
TEMP2 = SMATX(10,OS2)/SMATX(10,IS1)                                  DI202200
```

$$TEMP2 = \frac{TSS_{OS2}}{TSS_{IS1}} \quad [\text{no units}]$$

```
SMATX(10,OS1) = DMATX(2,N)                                           DI202300
```

$$TSS_{OS1} = TSS$$

```
SMATX(2,OS1) = (SMATX(10,IS1)-SMATX(10,OS2))*SMATX(2,IS1)/(SMATX(10,OS1)-SMATX(10,OS2))
```

$$Q_{OS1} = \frac{(TSS_{IS1} - TSS_{OS2})*Q_{IS1}}{(TSS_{OS1} - TSS_{OS2})} \quad [MGD]$$

DI202400

```
SMATX(2,OS2) = SMATX(2,IS1)-SMATX(2,OS1)                             DI202600
```

$$Q_{OS2} = Q_{IS1} - Q_{OS1} \quad [MGD]$$

```
SMATX(I,OS1) = TEMP1*SMATX(I,IS1)                                    DI203200
```

SMATX(I,OS1) = TEMP1*SMATX(I,IS1) [mg/l]

I = 3,9, i.e. SOC,SNBC,SON,SOP,SFM,SBOD,VSS

```
SMATX(I,OS2) = TEMP2*SMATX(I,IS1)                                    DI203300
```

SMATX(I,OS2) = TEMP2*SMATX(I,IS1)

I = 3,9

```
SMATX(I,OS1) = SMATX(I,IS1)                                        DI203500
```

$SMATX(I,OS1) = SMATX(I,IS1)$

I = 11,20 i.e. DOC,DNBC,DN,DP,DFM,ALK,DBOD,NH3,NO3

```
SMATX(I,OS2) = SMATX(I,IS1)                                        DI203600
```

$SMATX(I,OS2) = SMATX(I,IS1)$

I = 11,20

References:

Smith, 1969

Patterson and Banker, 1971

5. Cost functions.

   a. Capital cost

      Function of VDIG

```
X = ALOG(VDIG)                                                     DI204700
```

$X = \ln VDIG$

(1) Digester facilities less than 20000 ft^3

```
CCOST(N,1) = EXP(4.594215+.127244*X-.004001*X**2.)*1000.           DI205400
```

$$CCOST = 1000e^{4.594215+0.127244X-0.004001X^2} \quad \text{[dollars]}$$

(2) Digester facilities equal or greater than 20000 ft^3 DI206100

```
CCOST(N,1) = EXP(7.679634-1.949689*X+.402610*X**2.-.018211*X**3.)*1000.
```

$$CCOST = 1000e^{7.679634-1.949689X+0.402610X^2-0.018211X^3} \quad \text{[dollars]}$$

   b. Operating manhours, maintenance manhours, and materials/supplies costs

      Function of VDIG/ECF

```
X = ALOG(VDIG/DMATX(16,N))                                         DI206800
```

$X = \ln(VDIG/ECF)$

(1) Digester facilities less than 20000 ft^3

(a) Operating manhours

OHRS = EXP(6.163803+.166305*X-.012470*X**2.) DI207600

$$OHRS = e^{6.163803+0.166305X-0.012470X^2} \quad [hrs/yr]$$

(b) Maintenance manhours

XMHRS = EXP(5.726981+.113674*X) DI207700

$$XMHRS = e^{5.726981+0.113674X} \quad [hrs/yr]$$

(c) Total materials and supplies

TMSU = EXP(6.531623+.198417*X+.021660*X**2.) DI207800

$$TMSU = e^{6.531623+0.198417X+0.021660X^2} \quad [dollars/yr]$$

(2) Digester facilities equal or greater than 20000 ft^3

(a) Operating manhours DI208600

OHRS = EXP(9.129250-1.816736*X+.373282*X**2.-.017290*X**3.)

$$OHRS = e^{9.129250-1.816736X+0.373282X^2-0.017290X^3} \quad [hrs/yr]$$

(b) Maintenance manhours DI208700

XMHRS = EXP(8.566752-1.768137*X+.363173*X**2.-.016620*X**3.)

$$XMHRS = e^{8.566752-1.768137X+0.363173X^2-0.016620X^3} \quad [hrs/yr]$$

(c) Total materials and supplies DI208800

TMSU = EXP(8.702803-1.182711*X+.282691*X**2.-.013672*X**3.)

$$TMSU = e^{8.702803-1.182711X+0.282691X^2-0.013672X^3} \quad [dollars/yr]$$

c. Total operating and maintenance costs DI209300

COSTO(N,1) = ((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.

$$COSTO = \frac{(OHRS+XMHRS)DHR(1+PCT)+TMSU(WPI)}{Q_{Plant\ Inf.} \quad *3650} \quad [cents/1000\ gal]$$

```
C
C               SECOND STAGE ANAEROBIC DIGESTION
C               PROCESS IDENTIFICATION NUMBER  21
C
      SUBROUTINE DIG2
C
C
C               COMMON INITIAL STATEMENTS
C
      INTEGER OS1,OS2
      COMMON SMATX(20,30),TMATX(20,30),DMATX(20,20),OMATX(20,20),IP(20),
     1INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),ACOST(20,5)
     2,TCOST(20,5),DHR,PCT,WPI,CLAND,DLAND,FLOW(25),POW(25),TKWHD(25)
C
C
C               PROCESS RELATIONSHIPS REQD. TO CALC. EFFLUENT STREAM
C               CHARACTERISTICS
C
      SMATX(10,OS2)=((1.-DMATX(1,N))/(1.-DMATX(1,N)*SMATX(10,IS1)/DMATX(
     12,N)))*SMATX(10,IS1)
      TEMP1=DMATX(2,N)/SMATX(10,IS1)
      TEMP2=SMATX(10,OS2)/SMATX(10,IS1)
      SMATX(10,OS1)=DMATX(2,N)
      SMATX(2,OS1)=(SMATX(10,IS1)-SMATX(10,OS2))*SMATX(2,IS1)/(SMATX(10,
     1OS1)-SMATX(10,OS2))
      SMATX(2,OS2)=SMATX(2,IS1)-SMATX(2,OS1)
C
C
C               EFFLUENT STREAM CALCULATIONS
C
      DO 10 I=3,9
      SMATX(I,OS1)=TEMP1*SMATX(I,IS1)
   10 SMATX(I,OS2)=TEMP2*SMATX(I,IS1)
      DO 20 I=11,20
      SMATX(I,OS1)=SMATX(I,IS1)
   20 SMATX(I,OS2)=SMATX(I,IS1)
C
C
C              CALC. OF OUTPUT SIZES AND QUANTITIES
C
      VDIG=DMATX(3,N)*SMATX(2,IS1)*133.69*DMATX(16,N)
C
C
C              CALC. OF CAPITAL COSTS BASED ON DESIGN PLUS EXCESS
C              CAPACITY
C
      X=ALOG(VDIG)
      IF (VDIG-20.) 30,40,40
C
C
C                  CALC. OF CAPITAL COSTS FOR SMALL DIG2 FACILITY,
C                  LESS THAN 20000 CU. FT.
C
   30 CCOST(N,1)=EXP(4.594215+.127244*X-.004001*X**2.)*1000.
      GO TO 50
C
C
C                  CALC. OF CAPITAL COSTS FOR LARGE DIG2 FACILITY,
C                    EQUAL OR GREATER THAN 20000 CU. FT.
C
   40 CCOST(N,1)=EXP(7.679634-1.949689*X+.402610*X**2.-.018211*X**3.)*10
     100.
C
C
C              CALC. OF OPERATING COSTS BASED ON DESIGN CAPACITY ALONE,
C              DOES NOT INCLUDE EXCESS CAPACITY
C
   50 X=ALOG(VDIG/DMATX(16,N))
      IF (VDIG-20.) 60,70,70
C
C
C                    CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS
C                    AND MATERIALS AND SUPPLIES FOR DIG2 FACILITY, LESS
C                    THAN 20000 CU. FT.
C
   60 OHRS=EXP(6.163803+.166305*X-.012470*X**2.)
      XMHRS=EXP(5.726981+.113674*X)
      TMSU=EXP(6.531623+.198417*X+.021660*X**2.)
      GO TO 80
C
C
C                    CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS
C                    AND MATERIALS AND SUPPLIES FOR DIG2 FACILITY, EQUAL
C                    OR GREATER THAN 20000 CU. FT.
C
   70 OHRS=EXP(9.129250-1.816736*X+.373282*X**2.-.017290*X**3.)
      XMHRS=EXP(8.566752-1.768137*X+.363173*X**2.-.016620*X**3.)
      TMSU=EXP(8.702803-1.182711*X+.282691*X**2.-.013672*X**3.)
C
C
C                    OPERATING COST EQUATION
C
   80 COSTO(N,1)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.
C
C
C              ASSIGNMENT OF VALUES TO OMATX
C
      OMATX(1,N)=VDIG
C
C
C              PROCESS ENERGY INDICES
C
      FLOW(N)=SMATX(2,IS1)
      POW(N)=21.
      RETURN
      END
```

SECTION 23

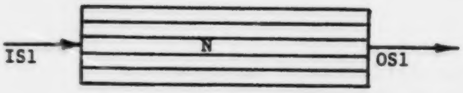
LAND DISPOSAL OF LIQUID SLUDGE, LANDD

Subroutine Identification Number 22

Land Disposal of Liquid Sludge, LANDD

Rev. Date 8/1/77

1. Process symbol.



IS1: Sludge input stream

OS1: Zero output since sludge percolates into soil

N: User assigned number to the process

2. Input parameters and nominal values.

DMATX(1,N) = TAYR	Amount of dry solids disposal, tons/acre/yr. [15.]
DMATX(2,N) = SP	Sludge storage period before disposal, yr. [.25]
DMATX(3,N) = DIST	Round trip sludge hauling distance by truck, miles. [10.]
DMATX(4,N) = TS	Sludge leading capacity of trucks used for hauling, gallons. [1200.]
DMATX(5,N) = YRSL	Amortization period for trucks, yr. [6.]
DMATX(15,N) = ECF	Excess capacity factor for trucking capacity. [1.]
DMATX(16,N) = ECF	Excess capacity factor for the sludge holding lagoon. [1.]

3. Output parameters which are printed on computer output sheets.

TAYR = DMATX(1,N)	
SP = DMATX(2,N)	
DIST = DMATX(3,N)	
TS = DMATX(4,N)	
YRSL = DMATX(5,N)	
TYT = OMATX(1,N)	Total number of trips made per year by each truck.
TTYR = OMATX(2,N)	Total number of trips made per year by all the trucks.

TRKN = OMATX(3,N)	Total number of trucks needed to haul the sludge.
SLV = OMATX(4,N)	Volume of sludge in storage, cu ft/1000.
TONS = OMATX(5,N)	Amount of dry solids applied to the land, tons/yr.
ALAND = OMATX(6,N)	Required land area for spreading the sludge (this land area requirement is not included in the total land area requirement, ACRE, for the whole plant), acre.
DLAND = OMATX(7,N)	Interest cost on the capital investment in land for sludge spreading, $/yr.
COL = OMATX(8,N)	Capital cost of land area required for sludge spreading, $.
AFT = OMATX(9,N)	Amortization factor for trucks based on a 6 year lifetime.
CCOST	Capital cost, [dollars].
COSTO	Operating and maintenance cost, [cents/1000 gal].
ACOST	Amortization cost, [cents/1000 gal].
TCOST	Total treatment cost, [cents/1000 gal].
ECF	Excess capacity factor.

4. Theory and functions - FORTRAN statement followed by equivalent algebraic equation.

```
TYT = 260.*8./(.04*DIST+.5)                  LAN02700
```

$$TYT = \frac{260*8}{0.04DIST+0.5}$$ [trips/yr/truck]

```
TTYR = 365.*SMATX(2,IS1)*1000000./TS         LAN02800
```

$$TTYR = \frac{365*1000000Q_{IS1}}{TS}$$ [trips/yr]

```
TRKN = TTYR/TYT                              LAN02900
```

$$TRKN = \frac{TTYR}{TYT}$$ [number]

```
NNN = TRKN*DMATX(15,N)                       LAN03000
```

$$NNN = TRKN*ECF$$ [number]

```
TRKN = NNN+1                                 LAN03100
```

$$TRKN = (TRKN*ECF)+1$$ [number]

`SLV = SP*365.*SMATX(2,IS1)*1000000./7.48/1000.*DMATX(16,N)` LAN03200

$$SLV = \frac{365SP*Q_{IS1}*1000000ECF}{7.48*1000} \qquad [ft^3/1000]$$

`TONS = (SMATX(10,IS1)+SMATX(15,IS1)*SMATX(2,IS1)*8.33*365./2000.` LAN03300

$$TONS = \frac{(TSS_{IS1}+DFM_{IS1})*Q_{IS1}*8.33*365}{2000} \qquad [tons/yr]$$

`ALAND = TONS/TAYR` LAN03400

$$ALAND = \frac{TONS}{TAYR} \qquad [acres]$$

`COL = ALAND*DMATX(7,20)` LAN03500

$$COL = ALAND*DA \qquad [dollars]$$

`DLAND = COL*DMATX(3,20)` LAN03600

$$DLAND = COL*RI \qquad [dollars]$$

`AF = DMATX(3,20)*(1.+DMATX(3,20))**DMATX(4,20)/((1.+DMATX(3,20))**DMATX(4,20)-1.)`

$$AF = \frac{RI*[1+RI]^{YRS}}{[1+RI]^{YRS}-1} \qquad [no\ units]$$ LAN03700

`AFT = DMATX(3,20)*(1.+DMATX(3,20))**YRSL/((1.+DMATX(3,20))**YRSL-1.)` LAN03900

$$AFT = \frac{RI*[1+RI]^{YRSL}}{[1+RI]^{YRSL}-1} \qquad [no\ units]$$

References:

Smith and Eilers, 1975

Patterson and Banker, 1971

5. Cost functions.

Sludge storage

a. Capital cost

Function of SLV

`X = ALOG(SLV)` LAN05000

$$X = \ln SLV$$

```
CCOST(N,1) = EXP(.375449+.394996*X+.014726*X**2.)*1000.                 LAN05100
```

$$CCOST = 1000e^{0.375449+0.394996X+0.014726X^2} \quad [\text{dollars}]$$

b. Operating manhours, maintenance manhours and materials/supplies costs

Function of TONS

```
X = ALOG(TONS)                                                          LAN05700
```

$$X = \ln TONS$$

(1) Operating manhours

```
OHRS = EXP(6.567594-.971759*X+.095689*X**2.)*SP                         LAN06300
```

$$OHRS = SP{*}e^{6.567594-0.971759X+0.095689X^2} \quad [\text{hrs/yr}]$$

(2) Maintenance manhours

```
XMHRS = EXP(-2.087393+2.395831*X-.340388*X**2.+.017499*X**3.)*SP        LAN06400
```

$$XMHRS = SP{*}e^{-2.087393+2.395831X-0.340388X^2+0.017499X^3} \quad [\text{hrs/yr}]$$

(3) Total materials and supplies

```
TMSU = 0                     [dollars/yr]                               LAN06500
```

c. Total operating and maintenance costs

```
COSTO(N,1) = ((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.      LAN07000
```

$$COSTO = \frac{[(OHRS+XMHRS)*DHR*(1+PCT)]+(TMSU*WPI)}{Q_{\text{Plant Inf.}}*3650} \quad [\text{cents/1000 gal}]$$

Sludge transportation

a. Capital cost

Function of TX

```
X = ALOG(TS/1000.)                                                      LAN07600
```

$$X = \ln \frac{TS}{1000}$$

```
CCOST(N,2) = EXP(1.317230+3.959678*X-2.592107*X**2.+.583467*X**3.)*(1.506/1.761)*1000*TRKN
```

$$CCOST = \frac{1.506}{1.761}*1000TRKN{*}e^{1.317230+3.959678X-2.592107X^2+0.583467X^3} \quad [\text{dollars}]$$

LAN07700

b. **Amortized cost**

ACOST(N,2) = CCOST(N,2)*AFT/SMATX(2,1)/3650. LAN08300

$$ACOST = \frac{CCOST*AFT}{Q_{Plant\ Inf.}*3650} \quad [cents/1000\ gal]$$

c. **Operating manhours, maintenance manhours and materials/supplies costs**

For TS $\geq$ 5500 LAN09400

OM = 0.475*DIST*TTYR [hrs/yr] LAN10000

For TS < 2500 LAN09500

OM = 0.305*DIST*TTYR [hrs/yr] LAN09600

For TS $\geq$ 2500 LAN09500

OM = 0.425*DIST*TTYR [hrs/yr] LAN09800

Maintenance manhours

TMHR = TTYR*(.04*DIST+.5) LAN10100

$$TMHR = TTYR*(0.04DIST+0.5) \quad [hrs/yr]$$

d. Total operating and maintenance costs

COSTO(N,2) = (TMHR*DHR*(1.+PCT)+OM*WPI)/SMATX(2,1)/3650. LAN10600

$$COSTO = \frac{[TMHR*DHR*(1+PCT)]+(OM*WPI)}{Q_{Plant\ Inf.}*3650} \quad [cents/1000\ gal]$$

Interest on capital investment

a. Capital cost assumed zero

CCOST(N,3) = 0 [dollars] LAN11200

b. Total operating and maintenance costs

COSTO(N,3) = DLAND/SMATX(2,1)/3650. LAN11300

$$COSTO = \frac{DLAND}{Q_{Plant\ Inf.}*3650} \quad [cents/1000\ gal]$$

```
C
C           LAND DISPOSAL OF LIQUID SLUDGE
C           PROCESS IDENTIFICATION NUMBER  22
C
      SUBROUTINE LANDD
C
C
C           COMMON INITIAL STATEMENTS
C
      INTEGER OS1,OS2
      COMMON SMATX(20,30),TMATX(20,30),DMATX(20,20),OMATX(20,20),IP(20),
     1INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),ACOST(20,5)
     2,TCOST(20,5),DHR,PCT,WPI,CLAND,DLAND,FLOW(25),POW(25),TKWHD(25)
C
C
C           ASSIGNMENT OF DESIGN VALUES TO PROCESS PARAMETERS
C
      TAYR=DMATX(1,N)
      SP=DMATX(2,N)
      DIST=DMATX(3,N)
      TS=DMATX(4,N)
      YRSL=DMATX(5,N)
C
C
C           CALC. OF OUTPUT SIZES AND QUANTITIES
C
      TYT=260.*8./(.04*DIST+.5)
      TTYR=365.*SMATX(2,IS1)*1000000./TS
      TRKN=TTYR/TYT
      NNN=TRKN*DMATX(15,N)
      TRKN=NNN+1
      SLV=SP*365.*SMATX(2,IS1)*1000000./7.48/1000.*DMATX(16,N)
      TONS=(SMATX(10,IS1)+SMATX(15,IS1))*SMATX(2,IS1)*8.33*365./2000.
      ALAND=TONS/TAYR
      COL=ALAND*DMATX(7,20)
      DLAND=COL*DMATX(3,20)
      AF=DMATX(3,20)*(1.+DMATX(3,20))**DMATX(4,20)/((1.+DMATX(3,20))**DM
     1ATX(4,20)-1.)
      AFT=DMATX(3,20)*(1.+DMATX(3,20))**YRSL/((1.+DMATX(3,20))**YRSL-1.)
C
C
C           COST CALCULATIONS
C
      IF (SLV) 10,20,10
C
C
C           CALC. OF CAPITAL COSTS FOR SLUDGE STORAGE BASED ON
C           DESIGN PLUS EXCESS CAPACITY
C
   10 X=ALOG(SLV)
      CCOST(N,1)=EXP(.375449+.394996*X+.014726*X**2.)*1000.
C
C
C           CALC. OF OPERATING COSTS FOR SLUDGE STORAGE BASED ON
C           DESIGN CAPACITY ALONE, DOES NOT INCLUDE EXCESS CAPACITY
C
      X=ALOG(TONS)
C
```

```
C
C                 CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS
C                 AND MATERIALS AND SUPPLIES
C
      OHRS=EXP(6.567594-.971759*X+.095689*X**2.)*SP
      XMHRS=EXP(-2.087393+2.395831*X-.340388*X**2.+.017499*X**3.)*SP
      TMSU=0.
C
C
C                 OPERATING COST EQUATION
C
      COSTO(N,1)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.
C
C
C             CALC. OF CAPITAL COSTS FOR SLUDGE TRANSPORTATION BASED
C             ON DESIGN PLUS EXCESS CAPACITY
C
   20 X=ALOG(TS/1000.)
      CCOST(N,2)=EXP(1.317230+3.959678*X-2.592107*X**2.+.583467*X**3.)*(
     11.506/1.761)*1000.*TRKN
C
C
C             CALC. OF AMORTIZATION COSTS
C
      ACOST(N,2)=CCOST(N,2)*AFT/SMATX(2,1)/3650.
C
C
C             CALC. OF OPERATING COSTS FOR SLUDGE TRANSPORTATION BASED
C             ON DESIGN CAPACITY ALONE, DOES NOT INCLUDE EXCESS
C             CAPACITY
C
C
C                 CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS
C                 AND MATERIALS AND SUPPLIES
C
      IF (TS-5500.) 30,60,60
   30 IF (TS-2500.) 40,50,50
   40 OM=.305*DIST*TTYR
      GO TO 70
   50 OM=.425*DIST*TTYR
      GO TO 70
   60 OM=.475*DIST*TTYR
   70 TMHR=TTYR*(.04*DIST+.5)
C
C
C                 OPERATING COST EQUATION
C
      COSTO(N,2)=(TMHR*DHR*(1.+PCT)+OM*WPI)/SMATX(2,1)/3650.
C
C
C             CALC. OF CAPITAL AND OPERATING COSTS FOR INTEREST ON
C             THE CAPITAL INVESTMENT
C
      CCOST(N,3)=0.
      COSTO(N,3)=DLAND/SMATX(2,1)/3650.
C
C
C             ASSIGNMENT OF VALUES TO OMATX
C
      OMATX(1,N)=TYT
      OMATX(2,N)=TTYR
      OMATX(3,N)=TRKN
      OMATX(4,N)=SLV
      OMATX(5,N)=TONS
      OMATX(6,N)=ALAND
      OMATX(7,N)=DLAND
      OMATX(8,N)=COL
      OMATX(9,N)=AFT
C
C
C             PROCESS ENERGY INDICES
C
      FLOW(N)=SMATX(2,IS1)
      POW(N)=22.
      RETURN
      END
```

SECTION 24

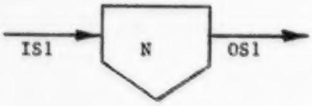
LIME ADDITION TO SLUDGE, LIME

Subroutine Identification Number 23

Lime Addition to Sludge, LIME

Rev. Date 8/1/77

1. Process symbol.



IS1: Sludge input stream

OS1: Sludge output stream

N: User assigned number to the process

2. Input parameters and nominal values.

DMATX(1,N) = DLIME	Dose of lime, lb of CaO/ton of dry solids. [200.]
DMATX(2,N) = CLIME	Cost of lime, $/ton. [25.]
DMATX(16,N) = ECF	Excess capacity factor for the process. [1.]

3. Output parameters which are printed on computer output sheets.

DLIME = DMATX(1,N)	
CLIME = DMATX(2,N)	
PPDL = OMATX(1,N)	Lime addition rate, lb of CaO/day.
DTON = OMATX(2,N)	Amount of sludge to be treated with lime, tons/day of dry solids.
CCOST	Capital cost , [dollars].
COSTO	Operating and maintenance cost, [cents/1000gal].
ACOST	Amortization cost, [cents/1000gal].
TCOST	Total treatment cost, [cents/1000gal].
ECF	Excess capacity factor.

4. Theory and functions - FORTRAN statement followed by equivalent algebraic equation.

DLIME = DMATX(1,N) LIM01800

$$DLIME = DMATX(1,N) \quad [\text{lb CaO/ton dry solids}]$$

CLIME = DMATX(2,N) LIM01900

$$CLIME = DMATX(2,N) \quad [\$/\text{ton}]$$

DTON = (SMATX(10,IS1)+SMATX(15,IS1))*SMATX(2,IS1)*8.33/2000.

$$DTON = \frac{[TSS_{IS1}+DFM_{IS1}]*Q_{IS1}*8.33}{2000} \quad [\text{tons/day}]$$ LIM02400

PPDL = DLIME * DTON * DMATX(16,N) LIM02500

$$PPDL = DLIME*DTON*ECF \quad [\text{lb/day}]$$

SMATX(I,OS1) = SMATX(I,IS1) LIM03100

$$SMATX(I,OS1) = SMATX(I,IS1) \quad [\text{mg/l}]$$

where I = 2,6

i.e. Q, SOC, SNBC, SON, SOP

SMATX(7,OS1) = SMATX(7,IS1)+PPDL/8.33/SMATX(2,IS1) LIM03200

$$SFM_{OSI}=SFM_{IS1}+\frac{PPDL}{8.33Q_{IS1}} \quad [\text{mg/l}]$$

SMATX(8,OS1) = SMATX(8,IS1) LIM03300

$$SBOD_{OS1}=SBOD_{IS1}$$

SMATX(9,OS1) = SMATX(9,IS1) LIM03400

$$VSS_{OS1}=VSS_{IS1}$$

SMATX(10,OS1) = SMATX(10,IS1)+PPDL/8.33/SMATX(2,IS1) LIM03500

$$TSS_{OS1}=TSS_{IS1}+\frac{PPDL}{8.33*Q_{IS1}} \quad [\text{mg/l}]$$

SMATX(I,OS1) = SMATX(I,IS1) LIM03700

$$SMATX(I,OS1) = SMATX(I,IS1)$$

where I = 11,20

i.e. DOC, DNBC, DN, DP, DFM, ALK, DBOD, NH3, NO3

References:

Smith and Eilers, 1975

Patterson and Banker, 1971

5. Cost functions.

a. Capital cost

Function of PPDL

```
X = ALOG(PPDL)                                    LIM04300
```

$$X = \ln PPDL$$

```
CCOST(N,1) = EXP(-1.800487+.670797*X)*1000.       LIM04400
```

$$CCOST = 1000e^{-1.800487+0.670797X} \quad [\text{dollars}]$$

b. Operating manhours, maintenance manhours and materials/supplies costs

Function of PPDL/ECF

```
X = ALOG(PPDL/DMATX(16,N))                        LIM05000
```

$$X = \ln \frac{PPDL}{ECF}$$

(1) Operating manhours

```
OHRS = 0.                                         LIM05500
```

$$OHRS = 0 \quad [\text{hrs/year}]$$

(2) Maintenance manhours

```
XMHRS = EXP(6.060054+.197073*X)                   LIM05600
```

$$XMHRS = e^{6.060054+0.197073X} \quad [\text{hrs/yr}]$$

(3) Total materials and supplies

```
CHEM = PPDL*365.*CLIME/2000.                      LIM06100
```

$$CHEM = \frac{PPDL*365*CLIME}{2000} \quad [\text{ton CaO/yr}]$$

c. Total operating and maintenance costs

```
COSTO(N,1) = ((OHRS+XMHRS)*DHR*(1.+PCT)+CHEM)/SMATX(2,1)/3650.
                                                  LIM06600
```

$$COSTO = \frac{[(OHRS+XMHRS)*DHR*(1+PCT)]+CHEM}{Q_{\text{Plant Inf.}}*3650} \quad [\text{cents/1000gal}]$$

```
C
C               LIME ADDITION TO SLUDGE
C               PROCESS IDENTIFICATION NUMBER  23
C
      SUBROUTINE LIME
C
C
C               COMMON INITIAL STATEMENTS
C
      INTEGER OS1,OS2
      COMMON SMATX(20,30),TMATX(20,30),DMATX(20,20),OMATX(20,20),IP(20),
     1INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),ACOST(20,5)
     2,TCOST(20,5),DHR,PCT,WPI,CLAND,DLAND,FLOW(25),POW(25),TKWHD(25)
C
C
C               ASSIGNMENT OF DESIGN VALUES TO CHEMICAL PARAMETERS
C
      DLIME=DMATX(1,N)
      CLIME=DMATX(2,N)
C
C
C               CALC. OF OUTPUT SIZES AND QUANTITIES
C
      DTON=(SMATX(10,IS1)+SMATX(15,IS1))*SMATX(2,IS1)*8.33/2000.
      PPDL=DLIME*DTON*DMATX(16,N)
C
C
C               EFFLUENT STREAM CALCULATIONS
C
      DO 10 I=2,6
   10 SMATX(I,OS1)=SMATX(I,IS1)
      SMATX(7,OS1)=SMATX(7,IS1)+PPDL/8.33/SMATX(2,IS1)
      SMATX(8,OS1)=SMATX(8,IS1)
      SMATX(9,OS1)=SMATX(9,IS1)
      SMATX(10,OS1)=SMATX(10,IS1)+PPDL/8.33/SMATX(2,IS1)
      DO 20 I=11,20
   20 SMATX(I,OS1)=SMATX(I,IS1)
C
C
C               CALC. OF CAPITAL COSTS BASED ON DESIGN PLUS EXCESS
C               CAPACITY
C
      X=ALOG(PPDL)
      CCOST(N,1)=EXP(-1.800487+.670797*X)*1000.
C
C
C               CALC. OF OPERATING COSTS BASED ON DESIGN CAPACITY ALONE.
C               DOES NOT INCLUDE EXCESS CAPACITY
C
      X=ALOG(PPDL/DMATX(16,N))
C
C
C                     CALC. OF OPERATING MANHOURS AND MAINTENANCE MANHOURS
C
      OHRS=0.
      XMHRS=EXP(6.060054+.197073*X)
C
C
```

```
C                   CALC. OF LIME DOSAGE COSTS                          LIM05900
C                                                                       LIM06000
      CHEM=PPDL*365.*CLIME/2000.                                        LIM06100
C                                                                       LIM06200
C                                                                       LIM06300
C                   OPERATING COST EQUATION                             LIM06400
C                                                                       LIM06500
      COSTO(N,1)=((OHRS+XMHRS)*DHR*(1.+PCT)+CHEM)/SMATX(2,1)/3650.      LIM06600
C                                                                       LIM06700
C                                                                       LIM06800
C             ASSIGNMENT OF VALUES TO OMATX                             LIM06900
C                                                                       LIM07000
      OMATX(1,N)=PPDL                                                   LIM07100
      OMATX(2,N)=DTON                                                   LIM07200
C                                                                       LIM07300
C                                                                       LIM07400
C             PROCESS ENERGY INDICES                                    LIM07500
C                                                                       LIM07600
      FLOW(N)=SMATX(2,IS1)                                              LIM07700
      POW(N)=23.                                                        LIM07800
      RETURN                                                            LIM07900
      END                                                               LIM08000
```

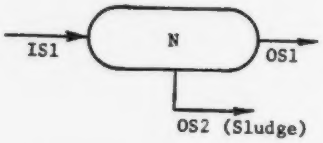
SECTION 25

ROTATING BIOLOGICAL CONTACTOR - FINAL SETTLER, RBC

Subroutine Identification Number 24

Rotating Biological Contactor - Final Settler, RBC Rev. Date 8/1/77

1. Process symbol.



IS1: Liquid input stream
OS1: Liquid output stream
OS2: Sludge output stream
N: User assigned number for the process

2. Input parameters and nominal values.

DMATX(1,N) = BOD	Demand concentration of 5-day BOD in the final effluent stream, mg/l.[13.]
DMATX(2,N) = XNSTG	Number of stages in series for the RBC process.[4.]
DMATX(3,N) = DEGC	Temperature of the water, degrees centrigrade. [20.]
DMATX(4,N) = QPABI	Rate constant for BOD removal at 20°C, gpd/sq ft.[7.]
DMATX(5,N) = QPANI	Rate constant for nitrification at 20°C, gpd/sq ft.[4.45]
DMATX(6,N) = GSS	Design overflow rate (based on average flow) for the final settler, gpd/sq ft.[800.]
DMATX(7,N) = BODN	Concentration of BOD at which nitrification begins, mg/l.[20.]
DMATX(8,N) = TSS	Concentration of waste solids from the final settler underflow, percent.[3.5]
DMATX(9,N) = CPDY	Cost of installed concrete, $/cu.yd.[233.]
DMATX(15,N) = ECF	Excess capacity factor for the final settler.[1.]
DMATX(16,N) = ECF	Excess capacity factor for the rotating biological contactor.[1.]

3. Output parameters which are printed on computer output sheets.

BOD = DMATX(1,N)	
XNSTG = DMATX(2,N)	
DEGC = DMATX(3,N)	
QPABI = DMATX(4,N)	
QPANI = DMATX(5,N)	
GSS = DMATX(6,N)	
BODN = DMATX(7,N)	
TSS = DMATX(8,N)	
CPDY = DMATX(9,N)	
QPAB = OMATX(1,N)	Rate constant for BOD removal after correction for water temperature, gpd/sq ft.
QPAN = OMATX(2,N)	Rate constant for nitrification after correction for water temperature, gpd/sq ft.
APSTG = OMATX(3,N)	Area per RBC stage, sq ft/stage.
AREA = OMATX(4,N)	Total RBC active area, sq ft.
FNSTG = OMATX(5,N)	Number of stages required to achieve the BOD concentration (BODN) at which nitrification begins.
RNSTG = OMATX(6,N)	Number of remaining stages for nitrification (XNSTG - FNSTG).
RATIO = OMATX(7,N)	Ratio of total BOD in the effluent stream to total BOD in the influent stream.
PREM = OMATX(8,N)	Percentage of ammonia nitrogen removal.
QPAT = OMATX(9,N)	Overall hydraulic loading, gpd/sq ft.
AFS = OMATX(10,N)	Surface area of the final settler, sq ft.
PDSD = OMATX(11,N)	Solids wasting rate, lb of dry solids/day.
URSS = OMATX(12,N)	Ratio of solid nonbiodegradable carbon concentration in the effluent stream to the concentration in the influent stream.

NTRN = OMATX(13,N)	**Number of 100,000 sq ft shafts per stage.**
NSHFT = OMATX(14,N)	**Number of 100,000 sq ft shafts required.**
COSTM = OMATX(15,N)	**Materials and supplies cost, $/yr.**
COSTE = OMATX(16,N)	**Electrical power cost, $/yr.**
COSTL = OMATX(17,N)	**Operation and maintenance labor cost, $/yr.**
CCOST	**Capital cost, [dollars].**
COSTO	**Operating and maintenance cost, [cents/1000gal].**
ACOST	**Amortization cost,[cents/1000gal].**
TCOST	**Total treatment cost,[cents/1000gal].**
ECF	**Excess capacity factor.**

4. Theory and functions - FORTRAN statement followed by equivalent algebraic equation.

```
QPAB = DMATX(4,N)*1.04**(DMATX(3,N)-20.)                          RBC03200
```

$$QPAB = QPABI*1.04^{DEGC-20} \qquad [gpd/ft^2]$$

```
QPAN = DMATX(5,N)*1.04**(DMATX(3,N)-20.)                          RBC03300
```

$$QPAN = QPANI*1.04^{DEGC-20} \qquad [gpd/ft^2]$$

```
RATIO = DMATX(1,N)/(SMATX(17,IS1)+SMATX(8,IS1))                   RBC03400
```

$$RATIO = \frac{BOD}{DBOD_{IS1}+SBOD_{IS1}} \qquad [no\ units]$$

```
TEMP1 = ALOG(RATIO)/DMATX(2,N)                                    RBC03500
```

$$TEMP1 = \frac{\ln RATIO}{XNSTG} \qquad [no\ units]$$

```
TEMP2 = 1./EXP(TEMP1)-1.                                          RBC03600
```

$$TEMP2 = \frac{1}{e^{TEMP1}} - 1 \qquad [no\ units]$$

```
APSTG = SMATX(2,IS1)*1000000.*TEMP2/QPAB                          RBC03700
```

$$APSTG = \frac{Q_{IS1}*1000000*TEMP2}{QPAB} \qquad [ft^2]$$

```
PDSD = .34*(SMATX(8,IS1)+SMATX(17,IS1)+SMATX(10,IS1))*SMATX(2,IS1)*8.33-.3*AREA/1000.
                                                                RBC03800
```

$$PDSD = 0.34(SBOD_{IS1}+DBOD_{IS1}+TSS_{IS1})*8.33Q_{IS1}-\frac{0.3AREA}{1000}$$

[lb/day]

```
TEMP3 = 1./(1.+QPAB*APSTG/SMATX(2,IS1)/1000000.)               RBC04000
```

$$TEMP3 = \frac{1}{1+\frac{QPAB*APSTG}{Q_{IS1}*1000000}}$$

[no units]

```
RATIO = DMATX(7,N)/(SMATX(17,IS1)+SMATX(8,IS1))                 RBC04100
```

$$RATIO = \frac{BODN}{DBOD_{IS1}+SBOD_{IS1}}$$

[no units]

```
FNSTG = ALOG(RATIO)/ALOG(TEMP3)                                 RBC04200
```

$$FNSTG = \frac{\ln RATIO}{\ln TEMP3}$$

[no units]

```
RNSTG = XNSTG-FNSTG                                             RBC04300
```

$$RNSTG = XNSTG-\frac{\ln RATIO}{\ln TEMP3}$$

[no units]

```
RATIO = (1./(1.+QPAN*APSTG/SMATX(2,IS1)/1000000.))**RNSTG       RBC04400
```

$$RATIO = \left[\frac{1}{1+\frac{QPAN*APSTG}{Q_{IS1}*1000000}}\right]^{RNSTG}$$

[no units]

```
SMATX(18,OS1) = SMATX(18,IS1)*RATIO                             RBC04900
```

$$NH3_{OS1} = NH3_{IS1}*RATIO$$

[mg/l]

```
SMATX(2,OS2) = PDSD/DMATX(8,N)/10000./8.33                      RBC05000
```

$$Q_{OS2} = \frac{PDSD}{TSS*10000*8.33}$$

[MGD]

```
SMATX(2,OS1) = SMATX(2,IS1)-SMATX(2,OS2)                        RBC05100
```

$$Q_{OS1} = Q_{IS1}-Q_{OS2}$$

[MGD]

```
SMATX(10,OS1) = 4.5+.51*DMATX(1,N)                              RBC05200
```

$$TSS_{OS1} = 4.5+0.51\ BOD$$

[mg/l]

```
SMATX(10,OS2) = DMATX(8,N)*10000                                    RBC05300
```

$TSS_{OS2} = 10000\ TSS$ [mg/l]

```
SMATX(8,OS1) = (SMATX(10,OS1)-4.5)*.897                             RBC05400
```

$SBOD_{OS1} = (TSS_{OS1}-4.5)*0.897$ [mg/l]

```
SMATX(17,OS1) = DMATX(1,N)-SMATX(8,OS1)                             RBC05500
```

$DBOD_{OS1} = BOD-SBOD_{OS1}$ [mg/l]

```
SMATX(19,OS1) = SMATX(18,IS1)-SMATX(18,OS1)                         RBC05600
```

$NO3_{OS1} = NH3_{IS1}-NH3_{OS1}$ [mg/l]

```
URSS = SMATX(2,IS1)/(SMATX(2,OS1)+SMATX(2,OS2)*SMATX(10,OS2)/SMATX(10,OS1))
```

RBC05700

$$URSS = \frac{Q_{IS1}}{Q_{OS1} + \frac{Q_{OS2}*TSS_{OS2}}{TSS_{OS1}}}$$

[no units]

```
SMATX(4,OS1) = URSS*SMATX(4,IS1)                                    RBC05900
```

$SNBC_{OS1} = URSS*SNBC_{IS1}$ [mg/l]

```
SMATX(3,OS1) = DMATX(1,N)*1.6/2.7+SMATX(4,OS1)                      RBC06000
```

$SOC_{OS1} = \frac{BOD*1.6}{2.7}+SNBC_{OS1}$ [mg/l]

```
SMATX(5,OS1) = .1*SMATX(3,OS1)                                      RBC06100
```

$SON_{OS1} = 0.1SOC_{OS1}$ [mg/l]

```
SMATX(6,OS1) = .01*SMATX(3,OS1)                                     RBC06200
```

$SOP_{OS1} = 0.01SOC_{OS1}$ [mg/l]

SMATX(7,OS1) = URSS*SMATX(7,IS1) RBC06300

$SFM_{OS1} = URSS*SFM_{IS1}$ [mg/1]

SMATX(9,OS1) = SMATX(10,OS1)-SMATX(7,OS1) RBC06400

$VSS_{OS1} = TSS_{OS1}-SFM_{OS1}$ [mg/1]

SMATX(11,OS1) = SMATX(12,IS1)+SMATX(17,OS1)*1.6/2.7 RBC06500

$DOC_{OS1} = DNBC_{IS1}+\frac{1.6DBOD_{OS1}}{2.7}$ [mg/1]

SMATX(12,OS1) = SMATX(12,IS1) RBC06600

$DNBC_{OS1} = DNBC_{IS1}$ [mg/1]

SMATX(13,OS1) = .1*SMATX(11,OS1)+SMATX(18,OS1)+SMATX(19,OS1) RBC06700

$DN_{OS1} = 0.1DOC_{OS1}+NH3_{OS1}+NO3_{OS1}$ [mg/1]

SMATX(14,OS1) = SMATX(14,IS1) RBC06800

$DP_{OS1} = DP_{IS1}$ [mg/1]

SMATX(15,OS1) = SMATX(15,IS1) RBC06900

$DFM_{OS1} = DFM_{IS1}$ [mg/1]

SMATX(16,OS1) = SMATX(16,IS1)-10.*(SMATX(18,IS1)-SMATX(18,OS1)) RBC07000

$ALK_{OS1} = ALK_{IS1}-10(NH3_{IS1}-NH3_{OS1})$ [mg/1]

SMATX(20,OS1) = SMATX(20,IS1) RBC07100

Future parameter [mg/1]

TEMP4 = SMATX(10,OS2)/SMATX(10,OS1) RBC07200

$TEMP4 = \frac{TSS_{OS2}}{TSS_{OS1}}$ [no units]

SMATX(J,OS2) = TEMP4*SMATX(J,OS1) RBC07400

$$\mathrm{SMATX(J,OS2) = TEMP4{*}SMATX(J,OS1)} \qquad [\mathrm{mg/l}]$$

where J = 3,9 i.e. SOC,SNBC,SON,SOP,SFM,SBOD,VSS

SMATX(J,OS2) = SMATX(J,OS1) RBC07600

$$\mathrm{SMATX(J,OS2) = SMATX(J,OS1)} \qquad [\mathrm{mg/l}]$$

where J = 11,20 i.e. DOC,DNBC,DN,DP,DFM,ALK,DBOD,NH3,NO3

AFS = SMATX(2,OS1)*1000000./DMATX(6,N)*DMATX(15,N) RBC08100

$$\mathrm{AFS} = \frac{\mathrm{Q_{OS1}{*}1000000{*}ECF}}{\mathrm{GSS}} \qquad [\mathrm{ft}^2]$$

PREM = (SMATX(18,IS1)-SMATX(18,OS1))*100./SMATX(18,IS1) RBC08200

$$\mathrm{PREM} = \frac{\mathrm{100(NH3_{IS1} - NH3_{OS1})}}{\mathrm{NH3_{IS1}}} \qquad [\text{no units}]$$

QPAT = SMATX(2,IS1)*1000000./APSTG/XNSTG RBC08300

$$\mathrm{QPAT} = \frac{\mathrm{Q_{IS1}{*}1000000}}{\mathrm{APSTG{*}XNSTG}} \qquad [\mathrm{gpd/ft}^2]$$

NTRN = APSTG*DMATX(16,N)/100000. RBC08400

$$\mathrm{NTRN} = \frac{\mathrm{APSTG{*}ECF}}{100000} \qquad [\text{no units}]$$

NSHFT = NTRN*XNSTG RBC08600

$$\mathrm{NSHFT = NTRN{*}XNSTG} \qquad [\text{no units}]$$

AREA = XSHFT*100000. RBC08900

$$\mathrm{AREA = 100000XSHFT} \qquad [\mathrm{ft}^2]$$

5. Cost functions.

Contactor

a. Capital cost

(1) $NSHFT-20 \leq 0$ RBC09500

```
CCOST(N,1) = (28500.+45.*DMATX(9,N))*NSHFT*1.506/2.1215          RBC10100
```

$$CCOST = \frac{(28500+45CPDY)*NSHFT*1.506}{2.1215} \quad [dollars]$$

(2) $NSHFT-20>0$ RBC09500

```
CCOST(N,1) = (23000.+45.*DMATX(9,N))*NSHFT*1.506/2.1215          RBC10800
```

$$CCOST = \frac{(23000+45CPDY)*NSHFT*1.506}{2.1215} \quad [dollars]$$

b. Operating manhours, maintenance manhours and materials/supplies costs

Function of AREA/ECF

```
X = ALOG(AREA/1000./DMATX(16,N))                                 RBC11400
```

$$X = \ln \frac{AREA}{1000ECF}$$

(1) Operating manhours

```
OHRS = EXP(1.323670+.524215*X+.023076*X**2.)                     RBC12000
```

$$OHRS = e^{1.323670+0.524215X+0.023076X^2} \quad [hrs/yr]$$

(2) Maintenance manhours

```
XMHRS = EXP(-.124185+.840104*X+.007757*X**2.)                    RBC12100
```

$$XMHRS = e^{-0.124185+0.840104X+0.007757X^2} \quad [hrs/yr]$$

(3) Total materials and supplies

```
COSTL = (OHRS+XMHRS)*DHR*(1.+PCT)                                RBC12200
```

$$COSTL = (OHRS+XMHRS)*DHR*(1+PCT) \quad [dollars/yr]$$

```
COSTM = (CCOST(N,1)-45.*DMATX(9,N)*NSHFT*1.506/2.1215)*.02            RBC12300
```

$$\mathrm{COSTM} = \left[\mathrm{CCOST} - \frac{45*\mathrm{CPDY}*\mathrm{NSHFT}*1.506}{2.1215}\right]*0.02 \qquad \text{[dollars/yr]}$$

```
COSTE = NSHFT*5.*.746*24.*365.*DMATX(10,20)                           RBC12400
```

$$\mathrm{COSTE} = \mathrm{NSHFT}*5*0.746*24*365*\mathrm{CKWH} \qquad \text{[dollars/yr]}$$

```
TMSU = COSTM+COSTE                                                    RBC12500
```

$$\mathrm{TMSU} = \mathrm{COSTM}+\mathrm{COSTE} \qquad \text{[dollars/yr]}$$

c. Total operating and maintenance costs

```
COSTO(N,1) = ((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU)/SMATX(2,1)/3650.        RBC13000
```

$$\mathrm{COSTO} = \frac{(\mathrm{OHRS}+\mathrm{XMHRS})*\mathrm{DHR}*(1+\mathrm{PCT})+\mathrm{TMSU}}{Q_{\text{Plant Inf.}}*3650} \qquad \text{[cents/1000gal]}$$

Final Settler

a. Capital cost

Function of AFS

```
X = ALOG(AFS/1000.)                                                   RBC13600
```

$$X = \ln \frac{\mathrm{AFS}}{1000}$$

```
CCOST(N,2) = EXP(3.716354+.389861*X+.084560*X**2.-.004718*X**3.)*1000.
                                                                      RBC13700
```

$$\mathrm{CCOST} = 1000e^{3.716354+0.389861X+0.084560X^2-0.004718X^3} \qquad \text{[dollars]}$$

b. Operating manhours, maintenance manhours, and materials/supplies costs

Function of AFS/ECF

```
X = ALOG(AFS/1000./DMATX(15,N))                                       RBC14400
```

$$X = \ln \frac{AFS}{1000ECF}$$

(1) Operating manhours

```
OHRS = EXP(5.846565+.254813*X+.113703*X**2.-.010942*X**3.)            RBC15000
```

$$OHRS = e^{5.846565+0.254813X+0.113703X^2-0.010942X^3} \qquad [\text{hrs/yr}]$$

(2) Maintenance manhours

```
XMHRS = EXP(5.273419+.228329*X+.122646*X**2.-.011672*X**3.)           RBC15100
```

$$XMHRS = e^{5.273419+0.228329X+0.122646X^2-0.011672X^3} \qquad [\text{hrs/yr}]$$

(3) Total materials and supplies

```
TMSU = EXP(5.669881+.750799*X)                                        RBC15200
```

$$TMSU = e^{5.669881+0.750799X} \qquad [\text{dollars/yr}]$$

c. Total operating and maintenance costs

```
COSTO(N,2) = ((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.   RBC15700
```

$$COSTO = \frac{[(OHRS+XMHRS)*DHR*(1+PCT)]+(TMSU*WPI)}{Q_{\text{Plant Inf.}}*3650} \qquad [\text{cents/1000gal}]$$

```
C
C               ROTATING BIOLOGICAL CONTACTOR - FINAL SETTLER
C               PROCESS IDENTIFICATION NUMBER  24
C
      SUBROUTINE RBC
C
C
C               COMMON INITIAL STATEMENTS
C
      INTEGER OS1,OS2
      COMMON SMATX(20,30),TMATX(20,30),DMATX(20,20),OMATX(20,20),IP(20),
     1INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),ACOST(20,5)
     2,TCOST(20,5),DHR,PCT,WPI,CLAND,DLAND,FLOW(25),POW(25),TKWHD(25)
C
C
C               ASSIGNMENT OF DESIGN VALUES TO PROCESS PARAMETERS
C
      BOD=DMATX(1,N)
      XNSTG=DMATX(2,N)
      DEGC=DMATX(3,N)
      QPABI=DMATX(4,N)
      QPANI=DMATX(5,N)
      GSS=DMATX(6,N)
      BODN=DMATX(7,N)
      TSS=DMATX(8,N)
      CPDY=DMATX(9,N)
C
C
C               PROCESS RELATIONSHIPS REQD. TO CALC. EFFLUENT STREAM
C               CHARACTERISTICS
C
      QPAB=DMATX(4,N)*1.04**(DMATX(3,N)-20.)
      QPAN=DMATX(5,N)*1.04**(DMATX(3,N)-20.)
      RATIO=DMATX(1,N)/(SMATX(17,IS1)+SMATX(8,IS1))
      TEMP1=ALOG(RATIO)/DMATX(2,N)
      TEMP2=1./EXP(TEMP1)-1.
      APSTG=SMATX(2,IS1)*1000000.*TEMP2/QPAB
      PDSD=.34*(SMATX(8,IS1)+SMATX(17,IS1)+SMATX(10,IS1))*SMATX(2,IS1)*8
     1.33-.3*AREA/1000.
      TEMP3=1./(1.+QPAB*APSTG/SMATX(2,IS1)/1000000.)
      RATIO=DMATX(7,N)/(SMATX(17,IS1)+SMATX(8,IS1))
      FNSTG=ALOG(RATIO)/ALOG(TEMP3)
      RNSTG=XNSTG-FNSTG
      RATIO=(1./(1.+QPAN*APSTG/SMATX(2,IS1)/1000000.))**RNSTG
C
C
C               EFFLUENT STREAM CALCULATIONS
C
      SMATX(18,OS1)=SMATX(18,IS1)*RATIO
      SMATX(2,OS2)=PDSD/DMATX(8,N)/10000./8.33
      SMATX(2,OS1)=SMATX(2,IS1)-SMATX(2,OS2)
      SMATX(10,OS1)=4.5+.51*DMATX(1,N)
      SMATX(10,OS2)=DMATX(8,N)*10000.
      SMATX(8,OS1)=(SMATX(10,OS1)-4.5)*.897
      SMATX(17,OS1)=DMATX(1,N)-SMATX(8,OS1)
      SMATX(19,OS1)=SMATX(18,IS1)-SMATX(18,OS1)
      URSS=SMATX(2,IS1)/(SMATX(2,OS1)+SMATX(2,OS2)*SMATX(10,OS2)/SMATX(1
     10,OS1))
```

```
      SMATX(4,OS1)=URSS*SMATX(4,IS1)                                    RBC05900
      SMATX(3,OS1)=DMATX(1,N)*1.6/2.7+SMATX(4,OS1)                      RBC06000
      SMATX(5,OS1)=.1*SMATX(3,OS1)                                      RBC06100
      SMATX(6,OS1)=.01*SMATX(3,OS1)                                     RBC06200
      SMATX(7,OS1)=URSS*SMATX(7,IS1)                                    RBC06300
      SMATX(9,OS1)=SMATX(10,OS1)-SMATX(7,OS1)                           RBC06400
      SMATX(11,OS1)=SMATX(12,IS1)+SMATX(17,OS1)*1.6/2.7                 RBC06500
      SMATX(12,OS1)=SMATX(12,IS1)                                       RBC06600
      SMATX(13,OS1)=.1*SMATX(11,OS1)+SMATX(18,OS1)+SMATX(19,OS1)        RBC06700
      SMATX(14,OS1)=SMATX(14,IS1)                                       RBC06800
      SMATX(15,OS1)=SMATX(15,IS1)                                       RBC06900
      SMATX(16,OS1)=SMATX(16,IS1)-10.*(SMATX(18,IS1)-SMATX(18,OS1))     RBC07000
      SMATX(20,OS1)=SMATX(20,IS1)                                       RBC07100
      TEMP4=SMATX(10,OS2)/SMATX(10,OS1)                                 RBC07200
      DO 10 J=3,9                                                       RBC07300
   10 SMATX(J,OS2)=TEMP4*SMATX(J,OS1)                                   RBC07400
      DO 20 J=11,20                                                     RBC07500
   20 SMATX(J,OS2)=SMATX(J,OS1)                                         RBC07600
C                                                                       RBC07700
C                                                                       RBC07800
C             CALC. OF OUTPUT SIZES AND QUANTITIES                      RBC07900
C                                                                       RBC08000
      AFS=SMATX(2,OS1)*1000000./DMATX(6,N)*DMATX(15,N)                  RBC08100
      PREM=(SMATX(18,IS1)-SMATX(18,OS1))*100./SMATX(18,IS1)             RBC08200
      QPAT=SMATX(2,IS1)*1000000./APSTG/XNSTG                            RBC08300
      NTRN=APSTG*DMATX(16,N)/100000.                                    RBC08400
      NTRN=NTRN+1                                                       RBC08500
      NSHFT=NTRN*XNSTG                                                  RBC08600
      XNTRN=NTRN                                                        RBC08700
      XSHFT=NSHFT                                                       RBC08800
      AREA=XSHFT*100000.                                                RBC08900
C                                                                       RBC09000
C                                                                       RBC09100
C             CALC. OF CAPITAL COSTS FOR ROTATING BIOLOGICAL CONTACTOR  RBC09200
C             BASED ON DESIGN PLUS EXCESS CAPACITY                      RBC09300
C                                                                       RBC09400
      IF (NSHFT-20) 30,30,40                                            RBC09500
C                                                                       RBC09600
C                                                                       RBC09700
C                   CALC. OF CAPITAL COSTS FOR SMALL RBC FACILITY, EQUAL RBC09800
C                   OR LESS THAN 20 SHAFTS                              RBC09900
C                                                                       RBC10000
   30 CCOST(N,1)=(28500.+45.*DMATX(9,N))*NSHFT*1.506/2.1215             RBC10100
      GO TO 50                                                          RBC10200
C                                                                       RBC10300
C                                                                       RBC10400
C                   CALC. OF CAPITAL COSTS FOR LARGE RBC FACILITY,      RBC10500
C                   GREATER THAN 20 SHAFTS                              RBC10600
C                                                                       RBC10700
   40 CCOST(N,1)=(23000.+45.*DMATX(9,N))*NSHFT*1.506/2.1215             RBC10800
C                                                                       RBC10900
C                                                                       RBC11000
C             CALC. OF OPERATING COSTS FOR RBC FACILITY BASED ON        RBC11100
C             DESIGN CAPACITY ALONE, DOES NOT INCLUDE EXCESS CAPACITY   RBC11200
C                                                                       RBC11300
   50 X=ALOG(AREA/1000./DMATX(16,N))                                    RBC11400
C                                                                       RBC11500
C                                                                       RBC11600
C                   CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS   RBC11700
C                   AND MATERIALS AND SUPPLIES                          RBC11800
C                                                                       RBC11900
      OHRS=EXP(1.323670+.524215*X+.023076*X**2.)                        RBC12000
      XMHRS=EXP(-.124185+.840104*X+.007757*X**2.)                       RBC12100
      COSTL=(OHRS+XMHRS)*DHR*(1.+PCT)                                   RBC12200
      COSTM=(CCOST(N,1)-45.*DMATX(9,N)*NSHFT*1.506/2.1215)*.02          RBC12300
      COSTE=NSHFT*5.*.746*24.*365.*DMATX(10,20)                         RBC12400
      TMSU=COSTM+COSTE
C
C
C                OPERATING COST EQUATION
C
      COSTO(N,1)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU)/SMATX(2,1)/3650.
C
C
C           CALC. OF CAPITAL COSTS FOR FINAL SETTLER BASED ON DESIGN
C           PLUS EXCESS CAPACITY
C
      X=ALOG(AFS/1000.)
      CCOST(N,2)=EXP(3.716354+.389861*X+.084560*X**2.-.004718*X**3.)*100
     10.
C
C
C           CALC. OF OPERATING COSTS FOR FINAL SETTLER BASED ON
C           DESIGN CAPACITY ALONE, DOES NOT INCLUDE EXCESS CAPACITY
C
      X=ALOG(AFS/1000./DMATX(15,N))
C
C
C                CALC. OF OPERATING MANHOURS, MAINTENANCE MANHOURS
C                AND MATERIALS AND SUPPLIES
C
      OHRS=EXP(5.846565+.254813*X+.113703*X**2.-.010942*X**3.)
      XMHRS=EXP(5.273419+.228329*X+.122646*X**2.-.011672*X**3.)
      TMSU=EXP(5.669881+.750799*X)
C
C
C                OPERATING COST EQUATION
C
      COSTO(N,2)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.
C
C
C           ASSIGNMENT OF VALUES TO OMATX
C
      OMATX(1,N)=QPAB
      OMATX(2,N)=QPAN
      OMATX(3,N)=APSTG
      OMATX(4,N)=AREA
      OMATX(5,N)=FNSTG
      OMATX(6,N)=RNSTG
      OMATX(7,N)=RATIO
      OMATX(8,N)=PREM
      OMATX(9,N)=QPAT
      OMATX(10,N)=AFS
      OMATX(11,N)=PDSD
      OMATX(12,N)=URSS
      OMATX(13,N)=XNTRN
      OMATX(14,N)=XSHFT
      OMATX(15,N)=COSTM
      OMATX(16,N)=COSTE
      OMATX(17,N)=COSTL
C
C
C           PROCESS ENERGY INDICES
C
      FLOW(N)=SMATX(2,IS1)
      POW(N)=24.
      RETURN
      END
```

SECTION 26

ENERGY CONSUMPTION AND COST, ENGY

```
C
C             ENERGY CONSUMPTION AND COST
C
      SUBROUTINE ENGY
C
C
C             COMMON INITIAL STATEMENTS
C
      INTEGER OS1,OS2
      COMMON SMATX(20,30),TMATX(20,30),DMATX(20,20),OMATX(20,20),IP(20),
     1INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),ACOST(20,5)
     2,TCOST(20,5),DHR,PCT,WPI,CLAND,DLAND,FLOW(25),POW(25),TKWHD(25)
C
C
C             ASSIGNMENT OF VALUES TO PROCESS PARAMETERS
C
      PLANT=DMATX(11,20)
      TOTKW=0.
      POW(25)=25.
C
C
C             CALC. OF ENERGY COSTS FOR PROCESSES
C
      DO 530 I=1,25
      FLOW(I)=SMATX(2,1)
      IF (POW(I)) 530,530,10
   10 K=POW(I)
      GO TO (20,30,40,50,60,70,110,140,170,180,190,220,270,280,310,370,3
     180,410,420,430,440,480,490,500,510), K
C
C
C                   PREL
C
   20 Q=ALOG(FLOW(I))
      MOT=EXP(Q)/15.001+1.
      HP=MOT*.75
      W1=.85*HP*24*.1
      W2=EXP(2.733863+.722304*Q-.070556*Q**2.+.007792*Q**3.)
      MOT=EXP(Q)/5.001+1.
      HP=MOT*.5
      W3=.85*HP*24.*.1667
      TKWHD(I)=W1+W2+W3
      GO TO 520
C
C
C                   PRSET
C
   30 Q=ALOG(FLOW(I))
      HP=EXP(.405835+.248262*Q+.138237*Q**2.-.009162*Q**3.)
      W1=.85*HP*24.
      W2=.64*EXP(Q)
      TKWHD(I)=W1+W2
      GO TO 520
C
C
C                   AERFS
C
   40 Q=ALOG(FLOW(I))
```

```
      W1=532.*EXP(Q)                                                    ENG05900
      W2=EXP(3.607707+.925147*Q+.046507*Q**2.-.010295*Q**3.)            ENG06000
      HP=EXP(.405835+.248262*Q+.138237*Q**2.-.009162*Q**3.)             ENG06100
      W3=.85*HP*24.                                                     ENG06200
      W4=2.66*EXP(Q)                                                    ENG06300
      TKWHD(I)=W1+W2+W3+W4                                              ENG06400
      GO TO 520                                                         ENG06500
C                                                                       ENG06600
C                                                                       ENG06700
C                  MIX                                                  ENG06800
C                                                                       ENG06900
   50 TKWHD(I)=0.                                                       ENG07000
      GO TO 520                                                         ENG07100
C                                                                       ENG07200
C                                                                       ENG07300
C                  SPLIT                                                ENG07400
C                                                                       ENG07500
   60 TKWHD(I)=0.                                                       ENG07600
      GO TO 520                                                         ENG07700
C                                                                       ENG07800
C                                                                       ENG07900
C                  DIG                                                  ENG08000
C                                                                       ENG08100
   70 Q=ALOG(FLOW(I))                                                   ENG08200
      IF (PLANT) 80,80,90                                               ENG08300
   80 W1=EXP(4.427327+.301912*Q+.056086*Q**2.-.005112*Q**3.)            ENG08400
      GO TO 100                                                         ENG08500
   90 W1=EXP(4.665033+.392918*Q+.074689*Q**2.-.017843*Q**3.+.001578*Q**4ENG08600
     1.)                                                                ENG08700
  100 W2=EXP(2.875478+.807735*Q+.033342*Q**2.-.006513*Q**3.)            ENG08800
      TKWHD(I)=W1+W2                                                    ENG08900
      GO TO 520                                                         ENG09000
C                                                                       ENG09100
C                                                                       ENG09200
C                  VACF                                                 ENG09300
C                                                                       ENG09400
  110 Q=ALOG(FLOW(I))                                                   ENG09500
      IF (PLANT) 120,120,130                                            ENG09600
  120 TKWHD(I)=EXP(2.342858+1.001088*Q+.021774*Q**2.-.006817*Q**3.)     ENG09700
      GO TO 520                                                         ENG09800
  130 TKWHD(I)=EXP(4.042635+.585417*Q+.114499*Q**2.-.010941*Q**3.)      ENG09900
      GO TO 520                                                         ENG10000
C                                                                       ENG10100
C                                                                       ENG10200
C                  THICK                                                ENG10300
C                                                                       ENG10400
  140 Q=ALOG(FLOW(I))                                                   ENG10500
      IF (PLANT) 150,150,160                                            ENG10600
  150 TKWHD(I)=EXP(2.321386+.286528*Q+.022247*Q**2.-.007060*Q**3.)      ENG10700
      GO TO 520                                                         ENG10800
  160 TKWHD(I)=EXP(2.321272+.301985*Q)                                  ENG10900
      GO TO 520                                                         ENG11000
C                                                                       ENG11100
C                                                                       ENG11200
C                  ELUT                                                 ENG11300
C                                                                       ENG11400
  170 TKWHD(I)=0.                                                       ENG11500
      GO TO 520                                                         ENG11600
C                                                                       ENG11700
C                                                                       ENG11800
C                  SBEDS                                                ENG11900
C                                                                       ENG12000
  180 TKWHD(I)=0.                                                       ENG12100
      GO TO 520                                                         ENG12200
C                                                                       ENG12300
C                                                                       ENG12400
```

```
C                    TRFS
C
  190 Q=ALOG(FLOW(I))
      W1=EXP(4.110844+.972364*Q-.002399*Q**2.)
      IF (DMATX(7,I)) 210,210,200
  200 W1=(DMATX(7,I)+1.)*W1
  210 HP=EXP(.405835+.248262*Q+.138237*Q**2.-.009162*Q**3.)
      W2=.85*HP*24.
      W3=2.66*EXP(Q)
      TKWHD(I)=W1+W2+W3
      GO TO 520
C
C
C                    CHLOR
C
  220 Q=ALOG(FLOW(I))
      IF (PLANT) 230,230,240
  230 TKWHD(I)=EXP(-.359521+2.273753*Q-.032634*Q**2.-.028066*Q**3.)
      GO TO 520
  240 IF (EXP(Q)-10.) 250,250,260
  250 TKWHD(I)=.72
      GO TO 520
  260 TKWHD(I)=EXP(-6.228734+2.563225*Q)
      GO TO 520
C
C
C                    TFLOT
C
  270 Q=ALOG(FLOW(I))
      TKWHD(I)=EXP(4.255944+.894471*Q+.040044*Q**2.-.007796*Q**3.)
      GO TO 520
C
C
C                    MHINC
C
  280 Q=ALOG(FLOW(I))
      IF (PLANT) 290,290,300
  290 TKWHD(I)=EXP(3.348899+.461306*Q+.149136*Q**2.-.013815*Q**3.)
      GO TO 520
  300 TKWHD(I)=EXP(3.990529+.423371*Q+.126216*Q**2.-.010836*Q**3.)
      GO TO 520
C
C
C                    RWP
C
  310 Q=ALOG(FLOW(I))
      IF (EXP(Q)-1.5) 320,320,330
  320 HE=.70
      GO TO 360
  330 IF (EXP(Q)-10.1) 340,340,350
  340 HE=.74
      GO TO 360
  350 HE=.85
  360 HP=EXP(Q)*1000000.*DMATX(1,I)/1440./3960./HE
      TKWHD(I)=.85*HP*24.
      GO TO 520
C
C
C                    SHT
C
  370 TKWHD(K)=0.
      GO TO 520
C
C
C                    CENT
C
```

```
  380 Q=ALOG(FLOW(I))                                                   ENG19100
      IF (PLANT) 390,390,400                                            ENG19200
  390 TKWHD(I)=EXP(3.332123+.919832*Q+.045490*Q**2.-.013202*Q**3.)      ENG19300
      GO TO 520                                                         ENG19400
  400 TKWHD(I)=EXP(4.042985+.813216*Q+.006793*Q**2.-.000180*Q**3.)      ENG19500
      GO TO 520                                                         ENG19600
C                                                                       ENG19700
C                                                                       ENG19800
C                  AEROB                                                ENG19900
C                                                                       ENG20000
  410 TKWHD(I)=0.                                                       ENG20100
      GO TO 520                                                         ENG20200
C                                                                       ENG20300
C                                                                       ENG20400
C                  POSTA                                                ENG20500
C                                                                       ENG20600
  420 TKWHD(I)=0.                                                       ENG20700
      GO TO 520                                                         ENG20800
C                                                                       ENG20900
C                                                                       ENG21000
C                  EQUAL                                                ENG21100
C                                                                       ENG21200
  430 TKWHD(I)=0.                                                       ENG21300
      GO TO 520                                                         ENG21400
C                                                                       ENG21500
C                                                                       ENG21600
C                  DIG2                                                 ENG21700
C                                                                       ENG21800
  440 Q=ALOG(FLOW(I))                                                   ENG21900
      IF (PLANT) 450,450,460                                            ENG22000
  450 W1=EXP(4.427327+.301912*Q+.056086*Q**2.-.005112*Q**3.)            ENG22100
      GO TO 470                                                         ENG22200
  460 W1=EXP(4.665033+.392918*Q+.074689*Q**2.-.017843*Q**3.+.001578*Q**4ENG22300
     1.)                                                                ENG22400
  470 W2=EXP(2.875478+.807735*Q+.033342*Q**2.-.006513*Q**3.)            ENG22500
      TKWHD(I)=W1+W2                                                    ENG22600
      GO TO 520                                                         ENG22700
C                                                                       ENG22800
C                                                                       ENG22900
C                  LANDD                                                ENG23000
C                                                                       ENG23100
  480 TKWHD(I)=0.                                                       ENG23200
      GO TO 520                                                         ENG23300
C                                                                       ENG23400
C                                                                       ENG23500
C                  LIME                                                 ENG23600
C                                                                       ENG23700
  490 TKWHD(I)=0.                                                       ENG23800
      GO TO 520                                                         ENG23900
C                                                                       ENG24000
C                                                                       ENG24100
C                  RBC                                                  ENG24200
C                                                                       ENG24300
  500 TKWHD(I)=0.                                                       ENG24400
      GO TO 520                                                         ENG24500
  510 Q=ALOG(SMATX(2,1))                                                ENG24600
      TKWHD(I)=EXP(4.047318+.198436*Q+.184937*Q**2.-.011184*Q**3.)      ENG24700
C                                                                       ENG24800
C                                                                       ENG24900
C             SUM OF ENERGY COSTS FOR ENTIRE PLANT                      ENG25000
C                                                                       ENG25100
  520 TOTKW=TOTKW+TKWHD(I)                                              ENG25200
  530 CONTINUE                                                          ENG25300
C                                                                       ENG25400
C                                                                       ENG25500
C             OUTPUT FORMAT OF ENERGY INDICES AND COSTS FOR PROCESSES   ENG25600
```

```
C              AND OF TOTAL ENERGY COST FOR ENTIRE PLANT
C
      WRITE (IO,540)
  540 FORMAT (1H1,//,47X,'ENERGY CONSUMPTION AND COST')
      WRITE (IO,550) (FLOW(I),I=1,25)
      WRITE (IO,550) (POW(I),I=1,25)
      WRITE (IO,550) (TKWHD(I),I=1,25)
  550 FORMAT (//,12F10.2,/,12F10.2,/,F10.2)
      WRITE (IO,560) TOTKW
  560 FORMAT (//,F10.2)
      RETURN
      END
```

SECTION 27

TOTAL PLANT COST CALCULATION, COST

Calculate Total Plant Cost, COST

Rev. Date 8/1/77

1. Input parameters and nominal values.

DMATX(1,20) = CCI	Sewage treatment plant construction cost index to account for the variation of construction cost with time, 1957-59 = 1. [2.257]
DMATX(2,20) = WPI	Wholesale price index for industrial commodities to account for the variation of materials and supplies cost with time, 1957-59 = 1. [1.675]
DMATX(3,20) = RI	Amortization interest rate, fraction. [.06]
DMATX(4,20) = YRS	Amortization period, yr. [25.]
DMATX(5,20) = DHR	Wastewater treatment plant hourly labor rate, \$/hr. [4.73]
DMATX(6,20) = PCT	Fraction of direct labor cost that is charged as indirect labor cost, fraction. [.15]
DMATX(7,20) = DA	Cost of land, \$/acre. [1000.]
DMATX(8,20) = CCINT	Interest rate for the cost of interest during plant construction, fraction. [.06]
DMATX(9,20) = XLAB	Program control: type of plant laboratory used, 1 = activated sludge, 0 = primary or trickling filter. [1.]
DMATX(10,20) = CKWH	Cost of electrical power, \$/kilowatt-hr.[.02]

2. Output parameters which are printed on computer output sheets.

CCI = DMATX(1,20)

RI = DMATX(3,20)

YRS = DMATX(4,20)

DA = DMATX(7,20)

CCINT = DMATX(8,20)

XLAB = DMATX(9,20)

RATIO = OMATX(1,20) Multiplier used to factor into individual unit process construction costs the cost of yardwork, land, engineering, legal & fiscal, and interest during construction, TOT/TCAP.

TCAP = OMATX(2,20)	Total capital cost of the entire treatment system without yardwork, land, engineering, legal & fiscal, and interest during construction costs factored in, \$.
YARD = OMATX(3,20)	Capital cost of yardwork, \$.
TCC = OMATX(4,20)	Subtotal of TCAP + YARD, \$.
XLAND = OMATX(5,20)	Cost of the required land for plant construction, \$.
ENG = OMATX(6,20)	Cost of the engineering services for plant construction, \$.
SUBT1 = OMATX(7,20)	Subtotal of TCAP+ YARD + XLAND & ENG, \$.
FISC = OMATX(8,20)	Cost of legal, fiscal and administrative services during plant construction, \$.
SUBT2 = OMATX(9,20)	Subtotal of TCAP + YARD + XLAND + ENG + FISC, \$.
XINT = OMATX(10,20)	Cost of interest during construction, \$.
ACRE = OMATX(11,20)	Total land requirement for the entire plant, acres.
AF = OMATX(12,20)	Amortization factor.
TOT = OMATX(17,20)	Total capital cost of the entire plant (SUBT2 + XINT), \$.
TAMM = OMATX(18,20)	Total amortization cost of the entire plant, ¢/1000 gallons.
TOPER = OMATX(19,20)	Total operation and maintenance cost of the entire plant, ¢/1000 gallons.
TOTAL = OMATX(20,20)	Total treatment cost of the entire plant (TAMM + TOPER), ¢/1000 gallons.

3. Theory and functions - FORTRAN statement followed by equivalent algebraic equation.

```
CCI = CCI/1.506                                        COS02700
```

$$CCI = \frac{CCI}{1.506} \qquad \text{[no units]}$$

```
AF = RI*(1.+RI)**YRS/((1.+RI)**YRS-1.)                 COS02800
```

$$AF = \frac{RI(1+RI)^{YRS}}{(1+RI)^{YRS}-1} \qquad \text{[no units]}$$

References:

Patterson and Banker, 1971

4. Cost functions.

Administrative and laboratory

a. Capital cost

Function of $Q_{\text{Plant Inf.}}$

```
X = ALOG(SMATX(2,1))                                              COS03400
```

$$X = \ln Q_{\text{Plant Inf.}}$$

```
CCOST(20,1) = EXP(3.524005+.383129 *X+ .077688*X**2.-.009021*X**3.)*1000.
                                                                  COS03500
```

$$CCOST = 1000e^{3.524005+.383129X+0.077688X^2-0.009021X^3}$$

[dollars]

b. Operating manhours, maintenance manhours and materials/supplies costs

(1) Operating manhours

```
OHRS = EXP(5.886104+.778820*X)                                    COS03700
```

$$OHRS = e^{5.886104+0.778820X}$$

[hrs/yr]

(2) Maintenance manhours

```
XMHRS = EXP(4.605170+.661110*X)                                   COS03800
```

$$XMHRS = e^{4.605170+0.661110X}$$

[hrs/yr]

(3) Total materials and supplies

```
TMSU = EXP(7.24422 6 +.500000*X)                                  COS03900
```

$$TMSU = e^{7.244226+0.500000X}$$

[dollars/yr]

c. Total operating and maintenance costs

```
COSTO(20,1) = ((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.
                                                                  COS04000
```

$$COSTO = \frac{(OHRS+XMHRS)DHR(1+PCT)+(TMSU*WPI)}{Q_{\text{Plant Inf.}}*3650}$$

[cents/1000 gal]

Garage and shop

a. Capital cost

CCOST(20,2) = EXP(2.28845D+.446606*X+.032729*X2.)*1000.** COS04500

$$CCOST = 1000e^{2.288450+0.446606X+0.032729X^2}$$ [dollars]

b. Operating manhours, maintenance manhours and materials/supplies costs

(1) Operating manhours COS04600

OHRS = 0 [hrs/yr]

(2) Maintenance manhours COS04700

XMHRS = 0 [hrs/yr]

(3) Total materials and supplies COS04800

TMSU = 0 [dollars/yr]

c. Total operating and maintenance costs COS04900

COSTO(20,2) = 0 [cents/1000 gal]

Laboratory operations

a. Capital cost COS05500

CCOST(20,3) = 0 [dollars]

b. Operating manhours, maintenance manhours and materials/supplies costs

(1) Operating manhours

(a) For XLAB = 0 Primary or trickling filter plant COS05600

OHRS = EXP(6.551080+.447632*X) COS05700

$$OHRS = e^{6.551080+0.447632X}$$ [hrs/yr]

(b) For XLAB=1 Activated sludge plant COS05600

`OHRS = EXP(7.892489+.087261*X+.004753*X**2.+.006532*X**3.)` COS05900

$$\mathrm{OHRS} = e^{7.892489+0.087261X+0.004753X^2+0.006532X^3}$$ [hrs/yr]

(2) Maintenance manhours

`XMHRS = EXP(4.700480+.368379*X)` COS06000

$$\mathrm{XMHRS} = e^{4.700480+0.368379X}$$ [hrs/yr]

(3) Total materials and supplies

`TMSU = EXP(5.972471+.534838*X+.010941*X**2.+.010320*X**3.)` COS06100

$$\mathrm{TMSU} = e^{5.972471+0.534838X+0.010941X^2+0.010320X^3}$$ [dollars/yr]

c. Total operating and maintenance costs

`COSTO(20,3) = ((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.` COS06200

$$\mathrm{COSTO} = \frac{(\mathrm{OHRS}+\mathrm{XMHRS})\mathrm{DHR}(1+\mathrm{PCT})+(\mathrm{TMSU}*\mathrm{WPI})}{Q_{\mathrm{Plant\ Inf.}}*3650}$$ [cents/1000 gal]

Yardwork operations

a. Capital cost COS06800

`CCOST(20,4) = 0` [dollars]

b. Operating manhours, maintenance manhours and materials/supplies costs

(1) Operating manhours COS06900

`OHRS = 0` [hrs/yr]

(2) Maintenance manhours

`XMHRS = EXP(6.542359+.082452*X+.184209*X**2.-.013606*X**3.)` COS07000

$$\mathrm{XMHRS} = e^{6.542359+0.082452X+0.184209X^2-0.013606X^3}$$ [hrs/yr]

(3) Total materials and supplies

`TMSU = EXP(5.991464+.650515*X)` COS07100

$$TMSU = e^{5.991464+0.650515X} \quad [\text{dollars/yr}]$$

c. Total operating and maintenance costs

`COSTO(20,4) = ((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.` COS07200

$$COSTO = \frac{(OHRS+XMHRS)DHR(1+PCT)+(TMSU*WPI)}{Q_{\text{Plant Inf.}}*3650} \quad [\text{cents/1000 gal}]$$

Intermediate plant costs

(1) `CCOST(J,I) = CCOST(J,I)*CCI/1000.` COS08000

$$CCOST = \frac{CCOST*CCI}{1000} \quad [\frac{\text{dollars}}{1000}]$$

where J = 1,20 and I = 1,5

(2) `TCAP = TCAP+CCOST(J,I)` COS08100

$$TCAP = TCAP+CCOST(J,I) \quad [\frac{\text{dollars}}{1000}]$$

where J = 1,20 and I = 1,5

(3) `YARD = .14*TCAP` COS08200

$$YARD = 0.14TCAP \quad [\frac{\text{dollars}}{1000}]$$

(4) `TCC = ALOG(TCAP+YARD)` COS08300

$$TCC = \ln\ (TCAP+YARD) \quad [\ln(\frac{\text{dollars}}{1000})]$$

`Q = ALOG(SMATX(2,1))` COS08400

$$Q = \ln\ Q_{\text{Plant Inf.}}$$

(5) `XLAND = EXP(2.405815+.010392*Q+.127563*Q**2.-.009133*Q**3.)*DA/1000.+CLAND/1000.`
`+DLAND/1000.` COS08500

$$XLAND = \frac{DA*e^{2.405815+0.010392Q+0.127563Q^2-0.009133Q^3}+CLAND+DLAND}{1000} \quad [\frac{\text{dollars}}{1000}]$$

(6) `ENG = EXP(.557449+.462790*TCC+.021284*TCC**2.)` COS08700

$ENG = e^{0.557449+0.462790TCC+0.021284TCC^2}$ $\left[\frac{\text{dollars}}{1000}\right]$

(7) `SUBT1 = ALOG(TCAP+YARD+XLAND+ENG)` COS08800

$SUBT1 = \ln\ (TCAP+YARD+XLAND+ENG)$ $\left[\ln\ (\frac{\text{dollars}}{1000})\right]$

(8) `FISC = EXP(-2.497954+.916338*SUBT1-.023887*SUBT1**2.)` COS08900

$FISC = e^{-2.497954+0.916338SUBT1-0.023887SUBT1^2}$ $\left[\frac{\text{dollars}}{1000}\right]$

(9) `SUBT2 = ALOG(TCAP+YARD+XLAND+ENG+FISC)` COS09000

$SUBT2 = \ln\ (TCAP+YARD+XLAND+ENG+FISC)$ $\left[\ln\ (\frac{\text{dollars}}{1000})\right]$

(10) `P =-1.475131+.428894*SUBT2)` COS09100

$P = -1.475131+0.428894SUBT2$ [no units]

(11) `XINT = CCINT*P/2.*EXP(SUBT2)` COS09200

$XINT = \frac{CCINT*P*e^{SUBT2}}{2}$ $\left[\frac{\text{dollars}}{1000}\right]$

(12) `TOT = TCAP+YARD+XLAND+ENG+FISC+XINT` COS09300

$TOT = TCAP+YARD+XLAND+ENG+FISC+XINT$ $\left[\frac{\text{dollars}}{1000}\right]$

(13) `TCC = EXP(TCC)` COS09400

$TCC = e^{TCC}$ $\left[\frac{\text{dollars}}{1000}\right]$

(14) `SUBT1 = EXP(SUBT1)` COS09500

$SUBT1 = e^{SUBT1}$ $\left[\frac{\text{dollars}}{1000}\right]$

(15) `SUBT2 = EXP(SUBT2)` COS09600

$SUBT2 = e^{SUBT2}$ $\left[\frac{\text{dollars}}{1000}\right]$

(16) `TCAP = TCAP*1000.` COS09700

$TCAP = 1000TCAP$ [dollars]

(17) TOT = TOT*1000. COS09800

$\text{TOT} = 1000\text{TOT}$ [dollars]

(18) YARD = YARD*1000. COS09900

$\text{YARD} = 1000\text{YARD}$ [dollars]

(19) TCC = TCC*1000. COS10000

$\text{TCC} = 1000\text{TCC}$ [dollars]

(20) XLAND = XLAND*1000. COS10100

$\text{XLAND} = 1000\text{XLAND}$ [dollars]

(21) ENG = ENG*1000. COS10200

$\text{ENG} = 1000\text{ENG}$ [dollars]

(22) SUBT1 = SUBT1*1000. COS10300

$\text{SUBT1} = 1000\text{SUBT1}$ [dollars]

(23) FISC = FISC*1000. COS10400

$\text{FISC} = 1000\text{FISC}$ [dollars]

(24) SUBT2 = SUBT2*1000. COS10500

$\text{SUBT2} = 1000\text{SUBT2}$ [dollars]

(25) XINT = XINT*1000. COS10600

$\text{XINT} = 1000\text{XINT}$ [dollars]

(26) RATIO = TOT/TCAP COS10700

$$\text{RATIO} = \frac{\text{TOT}}{\text{TCAP}}$$ [no units]

(27) ACRE = (XLAND-DLAND)/DA COS10800

$$\text{ACRE} = \frac{\text{XLAND-DLAND}}{\text{DA}}$$ [acres]

Total plant cost

a. Capital cost

CCOST(J,I) = CCOST(J,I)*1000.*RATIO

COS11900

CCOST = 1000CCOST*RATIO

[dollars]

where J = 1,20 and I = 1,5

b. Amortized cost

(1) For ACOST(J,I) = 0

COS12000

ACOST(J,I) = CCOST(J,I)*AF/SMATX(2,1)/3650.

COS12300

$$ACOST = \frac{CCOST*AF}{Q_{Plant\ Inf.}*3650}$$

[cents/1000 gal]

where J = 1,20 and I = 1,5

(2) For ACOST(J,I) > 0 Where ACOST calculated in subroutine e.g., LANDD,CENT

ACOST(J,I) = ACOST(J,I)*RATIO*CCI

COS12100

ACOST = ACOST*RATIO*CCI

[cents/1000 gal]

where J = 1,20 and I = 1,5

c. Treatment cost

TCOST(J,I) = COSTO(J,I)+ACOST(J,I)

COS12400

TCOST = COSTO+ACOST

[cents/1000 gal]

where J = 1,20 and I = 1,5

d. Total capital cost

TOT = TOT+CCOST(J,I)

COS12500

TOT = TOT+CCOST

$[\frac{dollars}{1000}]$

where J = 1,20 and I = 1,5

e. Total amortized cost

```
TAMM = TAMM+ACOST(J,I)                              COS12600
   TAMM = TAMM+ACOST                                [cents/1000 gal]
   where J = 1,20 and I = 1,5
```

f. Total operating cost

```
TOPER = TOPER+COSTO(J,I)                            COS12700
   TOPER = TOPER+COSTO                              [cents/1000 gal]
   where J = 1,20 and I = 1,5
```

g. Total treatment cost

```
TOTAL = TOTAL+TCOST(J,I)                            COS12800
   TOTAL = TOTAL+TCOST                              [cents/1000 gal]
   where J = 1,20 and I = 1,5
```

```
C
C              CALCULATE TOTAL PLANT COST
C
      SUBROUTINE COST
C
C
C              COMMON INITIAL STATEMENTS
C
      INTEGER OS1,OS2
      COMMON SMATX(20,30),TMATX(20,30),DMATX(20,20),OMATX(20,20),IP(20),
     1INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),ACOST(20,5)
     2,TCOST(20,5),DHR,PCT,WPI,CLAND,DLAND,FLOW(25),POW(25),TKWHD(25)
C
C
C              ASSIGNMENT OF DESIGN VALUES TO ECONOMIC PARAMETERS
C
      CCI=DMATX(1,20)
      RI=DMATX(3,20)
      YRS=DMATX(4,20)
      DA=DMATX(7,20)
      CCINT=DMATX(8,20)
      XLAB=DMATX(9,20)
C
C
C              CALC. OF OUTPUT QUANTITIES
C
      CCI=CCI/1.506
      AF=RI*(1.+RI)**YRS/((1.+RI)**YRS-1.)
C
C
C              CALC. OF CAPITAL AND OPERATING COSTS FOR ADMINISTRATIVE
C              AND LABORATORY
C
      X=ALOG(SMATX(2,1))
      CCOST(20,1)=EXP(3.524005+.383129*X+.077688*X**2.-.009021*X**3.)*10
     100.
      OHRS=EXP(5.886104+.778820*X)
      XMHRS=EXP(4.605170+.661110*X)
      TMSU=EXP(7.244226+.500000*X)
      COSTO(20,1)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.
C
C
C              CALC. OF CAPITAL AND OPERATING COSTS FOR GARAGE AND SHOP
C
      CCOST(20,2)=EXP(2.288450+.446606*X+.032729*X**2.)*1000.
      OHRS=0.
      XMHRS=0.
      TMSU=0.
      COSTO(20,2)=0.
C
C
C              CALC. OF CAPITAL AND OPERATING COSTS FOR LABORATORY
C              OPERATION
C
      CCOST(20,3)=0.
      IF (XLAB) 20,10,20
   10 OHRS=EXP(6.551080+.447632*X)
      GO TO 30
   20 OHRS=EXP(7.892489+.087261*X+.004753*X**2.+.006532*X**3.)
   30 XMHRS=EXP(4.700480+.368379*X)
      TMSU=EXP(5.972471+.534838*X+.010941*X**2.+.010320*X**3.)
      COSTO(20,3)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.
C
C
C             CALC. OF CAPITAL AND OPERATING COSTS FOR YARDWORK
C             OPERATION
C
      CCOST(20,4)=0.
      OHRS=0.
      XMHRS=EXP(6.542359+.062452*X+.184209*X**2.-.013606*X**3.)
      TMSU=EXP(5.991464+.650515*X)
      COSTO(20,4)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.
C
C
C             CALC. OF OUTPUT COSTS AND QUANTITIES
C
      TCAP=0.
      DO 40 J=1,20
      DO 40 I=1,5
      CCOST(J,I)=CCOST(J,I)*CCI/1000.
   40 TCAP=TCAP+CCOST(J,I)
      YARD=.14*TCAP
      TCC=ALOG(TCAP+YARD)
      Q=ALOG(SMATX(2,1))
      XLAND=EXP(2.405815+.010392*Q+.127563*Q**2.-.009133*Q**3.)*DA/1000.
     1+CLAND/1000.+DLAND/1000.
      ENG=EXP(.557449+.462790*TCC+.021284*TCC**2.)
      SUBT1=ALOG(TCAP+YARD+XLAND+ENG)
      FISC=EXP(-2.497954+.916338*SUBT1-.023887*SUBT1**2.)
      SUBT2=ALOG(TCAP+YARD+XLAND+ENG+FISC)
      P=-1.475131+.428894*SUBT2
      XINT=CCINT*P/2.*EXP(SUBT2)
      TOT=TCAP+YARD+XLAND+ENG+FISC+XINT
      TCC=EXP(TCC)
      SUBT1=EXP(SUBT1)
      SUBT2=EXP(SUBT2)
      TCAP=TCAP*1000.
      TOT=TOT*1000.
      YARD=YARD*1000.
      TCC=TCC*1000.
      XLAND=XLAND*1000.
      ENG=ENG*1000.
      SUBT1=SUBT1*1000.
      FISC=FISC*1000.
      SUBT2=SUBT2*1000.
      XINT=XINT*1000.
      RATIO=TOT/TCAP
      ACRE=(XLAND-DLAND)/DA
C
C
C             CALC. OF TOTAL COSTS OF ENTIRE PLANT
C
      TOT=0.
      TAMM=0.
      TOPER=0.
      TOTAL=0.
      DO 80 J=1,20
      DO 80 I=1,5
      CCOST(J,I)=CCOST(J,I)*1000.*RATIO
      IF (ACOST(J,I)) 50,60,50
   50 ACOST(J,I)=ACOST(J,I)*RATIO*CCI
      GO TO 70
   60 ACOST(J,I)=CCOST(J,I)*AF/SMATX(2,1)/3650.
   70 TCOST(J,I)=COSTO(J,I)+ACOST(J,I)
```

```
      TOT=TOT+CCOST(J,I)
      TAMM=TAMM+ACOST(J,I)
      TOPER=TOPER+COSTO(J,I)
   60 TOTAL=TOTAL+TCOST(J,I)
C
C
C              ASSIGNMENT OF VALUES TO OUTPUT DMATX
C
      DMATX(1,20)=CCI*1.506
      DMATX(2,20)=WPI*1.122
C
C
C              ASSIGNMENT OF VALUES TO OMATX
C
      OMATX(1,20)=RATIO
      OMATX(2,20)=TCAP
      OMATX(3,20)=YARD
      OMATX(4,20)=TCC
      OMATX(5,20)=XLAND
      OMATX(6,20)=ENG
      OMATX(7,20)=SUBT1
      OMATX(8,20)=FISC
      OMATX(9,20)=SUBT2
      OMATX(10,20)=XINT
      OMATX(11,20)=ACRE
      OMATX(12,20)=AF
      OMATX(17,20)=TOT
      OMATX(18,20)=TAMM
      OMATX(19,20)=TOPER
      OMATX(20,20)=TOTAL
      RETURN
      END
```

SECTION 28

OUTPUT SUBROUTINE, PRINT

```
C
C             PRINT OUTPUT
C
      SUBROUTINE PRINT
C
C
C             COMMON INITIAL STATEMENTS
C
      INTEGER OS1,OS2
      COMMON SMATX(20,30),TMATX(20,30),DMATX(20,20),OMATX(20,20),IP(20),
     1INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),ACOST(20,5)
     2,TCOST(20,5),DHR,PCT,WPI,CLAND,DLAND,FLOW(25),POW(25),TKWHD(25)
C
C
C             OUTPUT FORMAT FOR STREAM CHARACTERISTICS
C
      WRITE (IO,10)
   10 FORMAT (1H1,////,44X,'STREAM CHARACTERISTICS',//,66X,'VOLUME FLOW,
     1 MILLIONS OF GALLONS PER DAY',/,66X,'CONCENTRATIONS, MILLIGRAMS PE
     2R LITER',/)
      DO 40 I=1,30
      IF (SMATX(1,I)) 20,40,20
   20 WRITE (IO,30) (SMATX(J,I),J=1,9),SMATX(18,I),SMATX(16,I),(SMATX(J,
     1I),J=11,15),SMATX(17,I),SMATX(10,I),SMATX(19,I)
   30 FORMAT (2X,'S',F3.0,9X,'Q',8X,'SOC',7X,'SNBC',8X,'SON',8X,'SOP',8X
     1,'SFM',7X,'SBOD',8X,'VSS',8X,'NH3',/,7X,9F11.3,/,13X,'ALK',8X,'DOC
     2',7X,'DNBC',9X,'DN',9X,'DP',8X,'DFM',7X,'DBOD',8X,'TSS',8X,'NO3',/
     3,7X,9F11.3,//)
   40 CONTINUE
C
C
C             OUTPUT FORMAT FOR PROCESS CHARACTERISTICS AND PARAMETERS
C
      WRITE (IO,50)
   50 FORMAT (1H1,////,44X,'PROCESS CHARACTERISTICS',//,58X,'CCOST = CAP
     1ITAL COST, DOLLARS',/,58X,'COSTO = OPERATING + MAINTENANCE COST, C
     2ENTS/1000 GAL.',/,58X,'ACOST = AMORTIZATION COST, CENTS/1000 GAL.'
     3,/,58X,'TCOST = TOTAL TREATMENT COST, CENTS/1000 GAL.',//)
      DO 610 I=1,20
      IF (IP(I)) 60,610,60
   60 KK=IP(I)
      GO TO (70,90,110,610,610,140,160,180,200,220,240,270,300,320,350,3
     170,390,410,440,480,510,530,560,580), KK
C
C
C                  PREL
C
   70 WRITE (IO,80) I,DMATX(1,I),CCOST(I,1),COSTO(I,1),ACOST(I,1),TCOST(
     1I,1),DMATX(16,I)
   80 FORMAT (1X,1HP,I2,2X,'PRELIMINARY',6X,'IPREL',40X,'CCOST',4X,'COST
     1O',4X,'ACOST',4X,'TCOST',6X,'ECF',/,6X,'TREATMENT',6X,F9.1,36X,F9.
     20,3F9.3,F9.2,//)
      GO TO 610
C
C
C                  PRSET
C
   90 WRITE (IO,100) I,(DMATX(J,I),J=1,3),(OMATX(J,I),J=1,3),CCOST(I,1),
     1COSTO(I,1),ACOST(I,1),TCOST(I,1),DMATX(16,I),CCOST(I,2),COSTO(I,2)
     2,ACOST(I,2),TCOST(I,2),DMATX(15,I)
  100 FORMAT (1X,1HP,I2,2X,'PRIMARY',11X,'FRPS',5X,'URPS',5X,'HPWK',6X,'
     1GPS',6X,'APS',5X,'PGPM',/,6X,'SEDIMENTATION',2X,F9.2,3F9.1,F9.3,F9
     2.0,//,68X,'CCOST',4X,'COSTO',4X,'ACOST',4X,'TCOST',6X,'ECF',/,57X,
     3'SETTLER',2X,F9.0,3F9.3,F9.2,//,57X,'SLUDGE',3X,F9.0,3F9.3,F9.2,/,
     457X,'PUMPS',//)
      GO TO 610
C
C
C                   AERFS
C
  110 WRITE (IO,120) I,(DMATX(J,I),J=1,10),(OMATX(J,I),J=1,10)
  120 FORMAT (1X,1HP,I2,2X,'ACTIVATED SLUDGE-',2X,'BOD',5X,'MLSS',5X,'DE
     1GC',3X,'CAER20',7X,'DO',3X,'AEFF20',5X,'URSS',6X,'GSS',5X,'HEAD',5
     2X,'ALMD',/,6X,'FINAL SETTLER',2X,F9.1,F9.0,8F9.2,//,24X,'BOD2',4X,
     3'DOSAT',5X,'XRSS',6X,'AFS',5X,'CAER',5X,'CEDR',5X,'VAER',5X,'VNIT'
     4,4X,'MLASS',4X,'MLBSS',/,21X,2F9.1,F9.4,2F9.2,3F9.3,2F9.0/)
      WRITE (IO,130) (OMATX(J,I),J=11,20),CCOST(I,1),COSTO(I,1),ACOST(I,
     11),TCOST(I,1),DMATX(16,I),CCOST(I,2),COSTO(I,2),ACOST(I,2),TCOST(I
     2,2),DMATX(15,I),CCOST(I,3),COSTO(I,3),ACOST(I,3),TCOST(I,3),DMATX(
     314,I),CCOST(I,4),COSTO(I,4),ACOST(I,4),TCOST(I,4),DMATX(13,I)
  130 FORMAT (22X,'MLNBSS',4X,'MLDSS',4X,'MLISS',5X,'FOOD',4X,'RTURN',5X
     1,'CNIT',4X,'ARCFD',4X,'BSIZE',4X,'CFPGL',7X,'QR',/,21X,3F9.0,F9.1,
     22F9.3,2F9.0,F9.2,F9.3,//,68X,'CCOST',4X,'COSTO',4X,'ACOST',4X,'TCO
     3ST',6X,'ECF',/,57X,'AERATOR',2X,F9.0,3F9.3,F9.2,//,57X,'BLOWER',3X
     4,F9.0,3F9.3,F9.2,//,57X,'SLUDGE',3X,F9.0,3F9.3,F9.2,/,57X,'PUMPS',
     5//,57X,'FINAL',4X,F9.0,3F9.3,F9.2,/,57X,'SETTLER',//)
      GO TO 610
C
C
C                   DIG
C
  140 WRITE (IO,150) I,(DMATX(J,I),J=1,2),(OMATX(J,I),J=1,5),CCOST(I,1),
     1COSTO(I,1),ACOST(I,1),TCOST(I,1),DMATX(16,I)
  150 FORMAT (1X,1HP,I2,2X,'SINGLE STAGE',8X,'TD',5X,'TDIG',4X,'C1DIG',4
     1X,'C2DIG',5X,'VDIG',6X,'CH4',6X,'CO2',/,6X,'ANAEROBIC',6X,2F9.1,F9
     2.3,F9.0,F9.3,2F9.0,/,6X,'DIGESTION',/,68X,'CCOST',4X,'COSTO',4X,'A
     3COST',4X,'TCOST',6X,'ECF',/,66X,F9.0,3F9.3,F9.2,//)
      GO TO 610
C
C
C                   VACF
C
  160 WRITE (IO,170) I,(DMATX(J,I),J=1,10),(OMATX(J,I),J=1,3),CCOST(I,1)
     1,COSTO(I,1),ACOST(I,1),TCOST(I,1),DMATX(16,I)
  170 FORMAT (1X,1HP,I2,2X,'VACUUM',13X,'VFL',5X,'HPWK',6X,'TSS',4X,'IVA
     1CF',4X,'FECL3',6X,'CAO',4X,'CFECL',5X,'CCAO',4X,'DPOLY',4X,'CPOLY'
     2,/,6X,'FILTRATION',5X,F9.2,2F9.0,F9.1,2F9.2,2F9.4,F9.2,F9.4,//,26X
     3,'WP',6X,'AVF',5X,'PSUD',22X,'CCOST',4X,'COSTO',4X,'ACOST',4X,'TCO
     4ST',6X,'ECF',/,21X,2F9.1,F9.0,18X,F9.0,3F9.3,F9.2,//)
      GO TO 610
C
C
C                   THICK
C
  180 WRITE (IO,190) I,(DMATX(J,I),J=1,4),(OMATX(J,I),J=1,2),CCOST(I,1),
     1COSTO(I,1),ACOST(I,1),TCOST(I,1),DMATX(16,I)
  190 FORMAT (1X,1HP,I2,2X,'GRAVITY',12X,'TRR',6X,'TSS',6X,'GTH',5X,'GST
     1H',5X,'ATHM',6X,'WRT',/,6X,'THICKENING',5X,F9.2,F9.0,3F9.1,F9.2,//
     2,68X,'CCOST',4X,'COSTO',4X,'ACOST',4X,'TCOST',6X,'ECF',/,66X,F9.0,
     33F9.3,F9.2,//)
      GO TO 610
C
C
C                   ELUT
```

```
C                                                                       PRT12500
  200 WRITE (IO,210) I,(DMATX(J,I),J=1,5),OMATX(1,I),CCOST(I,1),COSTO(I,PRT12600
     11),ACOST(I,1),TCOST(I,1),DMATX(16,I)                              PRT12700
  210 FORMAT (1X,1HP,I2,2X,'ELUTRIATION',8X,'ERR',6X,'TSS',6X,'WRE',7X,'PRT12800
     1GE',6X,'GES',7X,'AE',/,21X,F9.2,F9.0,3F9.1,F9.0,//,68X,'CCOST',4X,PRT12900
     2'COSTO',4X,'ACOST',4X,'TCOST',6X,'ECF',/,66X,F9.0,3F9.3,F9.2,//)  PRT13000
      GO TO 610                                                         PRT13100
C                                                                       PRT13200
C                                                                       PRT13300
C                   SBEDS                                               PRT13400
C                                                                       PRT13500
  220 WRITE (IO,230) I,(DMATX(J,I),J=1,2),OMATX(1,I),CCOST(I,1),COSTO(I,PRT13600
     11),ACOST(I,1),TCOST(I,1),DMATX(16,I)                              PRT13700
  230 FORMAT (1X,1HP,I2,2X,'SAND DRYING',7X,'SOUT',6X,'TSS',6X,'ASB',22XPRT13800
     1,'CCOST',4X,'COSTO',4X,'ACOST',4X,'TCOST',6X,'ECF',/,6X,'BEDS',11XPRT13900
     2,F9.2,2F9.0,18X,F9.0,3F9.3,F9.2,//)                               PRT14000
      GO TO 610                                                         PRT14100
C                                                                       PRT14200
C                                                                       PRT14300
C                   TRFS                                                PRT14400
C                                                                       PRT14500
  240 WRITE (IO,250) I,(DMATX(J,I),J=1,9),(OMATX(J,I),J=1,4)            PRT14600
  250 FORMAT (1X,1HP,I2,2X,'TRICKLING',10X,'BOD',5X,'DEGC',7X,'HQ',4X,'SPRT14700
     1AREA',5X,'URSS',5X,'XRSS',3X,'RECYCL',6X,'GSS',5X,'HEAD',/,6X,'FILPRT14800
     2TER-',8X,F9.1,4F9.2,F9.4,3F9.1,/,6X,'FINAL SETTLER',/,25X,'AFS',6XPRT14900
     3,'VOL',4X,'FAREA',4X,'DEPTH',/,21X,F9.2,2F9.0,F9.2,/)             PRT15000
      WRITE (IO,260) CCOST(I,1),COSTO(I,1),ACOST(I,1),TCOST(I,1),DMATX(1PRT15100
     16,I),CCOST(I,2),COSTO(I,2),ACOST(I,2),TCOST(I,2),DMATX(15,I),CCOSTPRT15200
     2(I,3),COSTO(I,3),ACOST(I,3),TCOST(I,3),DMATX(14,I)                PRT15300
  260 FORMAT (68X,'CCOST',4X,'COSTO',4X,'ACOST',4X,'TCOST',6X,'ECF',/,57PRT15400
     1X,'FILTER',3X,F9.0,3F9.3,F9.2,//,57X,'FINAL',4X,F9.0,3F9.3,F9.2,/,PRT15500
     257X,'SETTLER',//,57X,'SLUDGE',3X,F9.0,3F9.3,F9.2,/,57X,'PUMPS',//)PRT15600
      GO TO 610                                                         PRT15700
C                                                                       PRT15800
C                                                                       PRT15900
C                   CHLOR                                               PRT16000
C                                                                       PRT16100
  270 WRITE (IO,280) I,(DMATX(J,I),J=1,5),(OMATX(J,I),J=1,3)            PRT16200
  280 FORMAT (1X,1HP,I2,2X,'CHLORINATION-',5X,'DCL2',5X,'TCL2',5X,'CCL2'PRT16300
     1,5X,'DSO2',5X,'CSO2',5X,'BVOL',5X,'CUSE',5X,'SUSE',/,6X,'DECHLORINPRT16400
     2ATION',1X,F9.2,F9.1,3F9.2,F9.0,2F9.2,/)                           PRT16500
      WRITE (IO,290) CCOST(I,1),COSTO(I,1),ACOST(I,1),TCOST(I,1),DMATX(1PRT16600
     16,I),CCOST(I,2),COSTO(I,2),ACOST(I,2),TCOST(I,2),DMATX(15,I),CCOSTPRT16700
     2(I,3),COSTO(I,3),ACOST(I,3),TCOST(I,3),DMATX(14,I)                PRT16800
  290 FORMAT (66X,'CCOST',4X,'COSTO',4X,'ACOST',4X,'TCOST',6X,'ECF',/,57PRT16900
     1X,'CONTACT',2X,F9.0,3F9.3,F9.2,/,57X,'BASIN',//,57X,'CL2 FEED',1X,PRT17000
     2F9.0,3F9.3,F9.2,/,57X,'SYSTEM',//,57X,'SO2 FEED',1X,F9.0,3F9.3,F9.PRT17100
     32,/,57X,'SYSTEM',//)                                              PRT17200
      GO TO 610                                                         PRT17300
C                                                                       PRT17400
C                                                                       PRT17500
C                   TFLOT                                               PRT17600
C                                                                       PRT17700
  300 WRITE (IO,310) I,(DMATX(J,I),J=1,7),(OMATX(J,I),J=1,3),CCOST(I,1),PRT17800
     1COSTO(I,1),ACOST(I,1),TCOST(I,1),DMATX(16,I)                      PRT17900
  310 FORMAT (1X,1HP,I2,2X,'FLOTATION',10X,'TRR',6X,'TSS',6X,'GTH',5X,'GPRT18000
     1STH',5X,'HPWK',4X,'DPOLY',4X,'CPOLY',/,6X,'THICKENING',5X,F9.2,F9.PRT18100
     20,5F9.2,//,24X,'ATHM',7X,'XN',4X,'ATHM1',22X,'CCOST',4X,'COSTO',4XPRT18200
     3,'ACOST',4X,'TCOST',6X,'ECF',/,21X,3F9.1,18X,F9.0,3F9.3,F9.2,//)  PRT18300
      GO TO 610                                                         PRT18400
C                                                                       PRT18500
C                                                                       PRT18600
C                   MHINC                                               PRT18700
C                                                                       PRT18800
  320 WRITE (IO,330) I,(DMATX(J,I),J=1,9),(OMATX(J,I),J=1,5)            PRT18900
  330 FORMAT (1X,1HP,I2,2X,'MULTIPLE HEARTH',5X,'ML',5X,'NINC',5X,'HPWK'PRT19000
     1,5X,'SPER',7X,'WV',7X,'HV',5X,'TYPE',7X,'FC',6X,'CNG',/,6X,'INCINEPRT19100
     2RATION',3X,7F9.1,2F9.3,//,25X,'FHA',5X,'WFYR',5X,'PSDD',4X,'ECOST'PRT19200
     3,4X,'FCOST',/,21X,5F9.0,/)                                        PRT19300
      WRITE (IO,340) CCOST(I,1),COSTO(I,1),ACOST(I,1),TCOST(I,1),DMATX(1PRT19400
     16,I)                                                              PRT19500
  340 FORMAT (68X,'CCOST',4X,'COSTO',4X,'ACOST',4X,'TCOST',6X,'ECF',/,66PRT19600
     1X,F9.0,3F9.3,F9.2,//)                                             PRT19700
      GO TO 610                                                         PRT19800
C                                                                       PRT19900
C                                                                       PRT20000
C                       RWP                                             PRT20100
C                                                                       PRT20200
  350 WRITE (IO,360) I,DMATX(1,I),OMATX(1,I),CCOST(I,1),COSTO(I,1),ACOSTPRT20300
     1(I,1),TCOST(I,1),DMATX(16,I)                                      PRT20400
  360 FORMAT (1X,1HP,I2,2X,'RAW WASTEWATER',4X,'HEAD',7X,'QP',31X,'CCOSTPRT20500
     1',4X,'COSTO',4X,'ACOST',4X,'TCOST',6X,'ECF',/,6X,'PUMPING',8X,2F9.PRT20600
     22,27X,F9.0,3F9.3,F9.2,//)                                         PRT20700
      GO TO 610                                                         PRT20800
C                                                                       PRT20900
C                                                                       PRT21000
C                       SHT                                             PRT21100
C                                                                       PRT21200
  370 WRITE (IO,380) I,DMATX(1,I),OMATX(1,I),CCOST(I,1),COSTO(I,1),ACOSTPRT21300
     1(I,1),TCOST(I,1),DMATX(16,I)                                      PRT21400
  380 FORMAT (1X,1HP,I2,2X,'SLUDGE HOLDING',6X,'TD',5X,'VSHT',31X,'CCOSTPRT21500
     1',4X,'COSTO',4X,'ACOST',4X,'TCOST',6X,'ECF',/,6X,'TANKS',10X,2F9.1PRT21600
     2,27X,F9.0,3F9.3,F9.2,//)                                          PRT21700
      GO TO 610                                                         PRT21800
C                                                                       PRT21900
C                                                                       PRT22000
C                       CENT                                            PRT22100
C                                                                       PRT22200
  390 WRITE (IO,400) I,(DMATX(J,I),J=1,8),(OMATX(J,I),J=1,5),CCOST(I,1),PRT22300
     1COSTO(I,1),ACOST(I,1),TCOST(I,1),DMATX(16,I)                      PRT22400
  400 FORMAT (1X,1HP,I2,2X,'CENTRIFUGATION',5X,'CRR',6X,'TSS',5X,'HPWK',PRT22500
     15X,'XCEN',5X,'POLY',4X,'CPOLY',5X,'GPMN',4X,'CNMIN',/,21X,F9.2,F9.PRT22600
     20,3F9.1,2F9.2,F9.1,//,24X,'CGPM',5X,'DSOL',6X,'AFC',4X,'CSIZE',7X,PRT22700
     3'CN',/,21X,F9.0,F9.1,F9.5,2F9.1,//,68X,'CCOST',4X,'COSTO',4X,'ACOSPRT22800
     4T',4X,'TCOST',6X,'ECF',/,66X,F9.0,3F9.3,F9.2,//)                  PRT22900
      GO TO 610                                                         PRT23000
C                                                                       PRT23100
C                                                                       PRT23200
C                       AEROB                                           PRT23300
C                                                                       PRT23400
  410 WRITE (IO,420) I,(DMATX(J,I),J=1,8),(OMATX(J,I),J=1,4)            PRT23500
  420 FORMAT (1X,1HP,I2,2X,'AEROBIC',13X,'XL',5X,'XAFS',6X,'DTA',5X,'TSSPRT23600
     11',5X,'TSS2',5X,'BOD2',6X,'GSS',5X,'HEAD',/,6X,'DIGESTION',6X,2F9.PRT23700
     20,F9.1,2F9.0,F9.1,2F9.2,//,24X,'VAER',5X,'ACFM',4X,'QPUMP',6X,'AFSPRT23800
     3',/,21X,F9.3,F9.0,2F9.2,/)                                        PRT23900
      WRITE (IO,430) CCOST(I,1),COSTO(I,1),ACOST(I,1),TCOST(I,1),DMATX(1PRT24000
     16,I),CCOST(I,2),COSTO(I,2),ACOST(I,2),TCOST(I,2),DMATX(15,I),CCOSTPRT24100
     2(I,3),COSTO(I,3),ACOST(I,3),TCOST(I,3),DMATX(14,I),CCOST(I,4),COSTPRT24200
     30(I,4),ACOST(I,4),TCOST(I,4),DMATX(13,I)                          PRT24300
  430 FORMAT (68X,'CCOST',4X,'COSTO',4X,'ACOST',4X,'TCOST',6X,'ECF',/,57PRT24400
     1X,'AERATOR',2X,F9.0,3F9.3,F9.2,//,57X,'BLOWER',3X,F9.0,3F9.3,F9.2,PRT24500
     2//,57X,'SLUDGE',3X,F9.0,3F9.3,F9.2,/,57X,'PUMPS',//,57X,'FINAL',4XPRT24600
     3,F9.0,3F9.3,F9.2,/,57X,'SETTLER',//)                              PRT24700
      GO TO 610                                                         PRT24800
C                                                                       PRT24900
C                                                                       PRT25000
C                       POSTA                                           PRT25100
C                                                                       PRT25200
  440 WRITE (IO,450) I,(DMATX(J,I),J=1,13),(OMATX(J,I),J=1,7)           PRT25300
  450 FORMAT (1X,1HP,I2,2X,'POST AERATION',4X,'ITYPE',8X,'L',5X,'DOIN',5PRT25400
     1X,'DOUT',7X,'TL',7X,'TD',7X,'TW',4X,'AERFO',4X,'HPHRO',6X,'ALT',/,PRT25500
     221X,2F9.0,5F9.1,F9.3,2F9.2,//,23X,'CFMDF',4X,'DIFFT',7X,'DD',5X,'VPRT25600
     3AER',6X,'CFM',7X,'HP',5X,'TMIN',6X,'VMG',4X,'AERFF',5X,'CLEN',/,21
     4X,3F9.1,F9.3,F9.0,2F9.2,F9.4,F9.3,F9.2,/)
      WRITE (IO,460) (OMATX(J,I),J=8,13)
  460 FORMAT (25X,'HP1',7X,'XN',6X,'THP',4X,'WIDTH',4X,'DEPTH',5X,'TLEN'
     1,/,21X,F9.2,F9.1,F9.2,2F9.1,F9.2,/)
      WRITE (IO,470) CCOST(I,1),COSTO(I,1),ACOST(I,1),TCOST(I,1),DMATX(1
     16,I),CCOST(I,2),COSTO(I,2),ACOST(I,2),TCOST(I,2),DMATX(15,I)
  470 FORMAT (68X,'CCOST',4X,'COSTO',4X,'ACOST',4X,'TCOST',6X,'ECF',/,57
     1X,'BASIN',4X,F9.0,3F9.3,F9.2,//,57X,'AIR',6X,F9.0,3F9.3,F9.2,/,57X
     2,'SUPPLY',//)
      GO TO 610
C
C
C                  EQUAL
C
  480 WRITE (IO,490) I,(DMATX(J,I),J=1,5),(OMATX(J,I),J=1,14)
  490 FORMAT (1X,1HP,I2,2X,'EQUALIZATION',6X,'IAER',6X,'RLW',4X,'COSTL',
     15X,'HEAD',5X,'IMAT',4X,'WIDTH',5X,'AREA',5X,'VUMG',5X,'VOMG',7X,'V
     2T',/,21X,2F9.1,F9.3,2F9.1,F9.2,F9.4,3F9.4,//,23X,'SAREA',7X,'HP',6
     3X,'HP1',7X,'XN',6X,'THP',4X,'PLAND',4X,'CLAND',5X,'VAER',5X,'ECFM'
     4,/,21X,F9.1,2F9.2,F9.1,2F9.2,F9.0,F9.3,F9.0,/)
      WRITE (IO,500) CCOST(I,1),COSTO(I,1),ACOST(I,1),TCOST(I,1),DMATX(1
     16,I),CCOST(I,2),COSTO(I,2),ACOST(I,2),TCOST(I,2),DMATX(15,I),CCOST
     2(I,3),COSTO(I,3),ACOST(I,3),TCOST(I,3),DMATX(14,I),CCOST(I,4),COST
     3O(I,4),ACOST(I,4),TCOST(I,4),CCOST(I,5),COSTO(I,5),ACOST(I,5),TCOS
     4T(I,5)
  500 FORMAT (68X,'CCOST',4X,'COSTO',4X,'ACOST',4X,'TCOST',6X,'ECF',/,57
     1X,'AERATED',2X,F9.0,3F9.3,F9.2,/,57X,'POND/TANK',//,57X,'AIR',6X,F
     29.0,3F9.3,F9.2,/,57X,'SUPPLY',//,57X,'PUMPING',2X,F9.0,3F9.3,F9.2,
     3/,57X,'SYSTEM',//,57X,'FLOW',5X,F9.0,3F9.3,/,57X,'MEASURING',//,57
     4X,'POND',5X,F9.0,3F9.3,/,57X,'LINING',//)
      GO TO 610
C
C
C                  DIG2
C
  510 WRITE (IO,520) I,(DMATX(J,I),J=1,3),OMATX(1,I),CCOST(I,1),COSTO(I,
     11),ACOST(I,1),TCOST(I,1),DMATX(16,I)
  520 FORMAT (1X,1HP,I2,2X,'SECOND STAGE',7X,'TRR',6X,'TSS',7X,'TD',5X,'
     1VDIG',13X,'CCOST',4X,'COSTO',4X,'ACOST',4X,'TCOST',6X,'ECF',/,6X,'
     2ANAEROBIC',6X,F9.2,F9.0,F9.1,F9.3,9X,F9.0,3F9.3,F9.2,/,6X,'DIGESTI
     3ON',//)
      GO TO 610
C
C
C                  LANDD
C
  530 WRITE (IO,540) I,(DMATX(J,I),J=1,5),(OMATX(J,I),J=1,9)
  540 FORMAT (1X,1HP,I2,2X,'LAND DISPOSAL OF',2X,'TAYR',7X,'SP',5X,'DIST
     1',7X,'TS',5X,'YRSL',/,6X,'LIQUID SLUDGE',2X,3F9.2,F9.0,F9.1,//,25X
     2,'TYT',5X,'TTYR',5X,'TRKN',6X,'SLV',5X,'TONS',4X,'ALAND',4X,'DLAND
     3',6X,'COL',6X,'AFT',/,21X,3F9.0,3F9.2,2F9.0,F9.5,/)
      WRITE (IO,550) CCOST(I,1),COSTO(I,1),ACOST(I,1),TCOST(I,1),DMATX(1
     16,I),CCOST(I,2),COSTO(I,2),ACOST(I,2),TCOST(I,2),DMATX(15,I),CCOST
     2(I,3),COSTO(I,3),ACOST(I,3),TCOST(I,3)
  550 FORMAT (68X,'CCOST',4X,'COSTO',4X,'ACOST',4X,'TCOST',6X,'ECF',/,57
     1X,'STORAGE',2X,F9.0,3F9.3,F9.2,/,57X,'LAGOON',//,57X,'TRUCKING',1X
     2,F9.0,3F9.3,F9.2,//,57X,'INTEREST',1X,F9.0,3F9.3,/,57X,'ON LAND',/
     3/)
      GO TO 610
C
C
C                  LIME
C
  560 WRITE (IO,570) I,(DMATX(J,I),J=1,2),(OMATX(J,I),J=1,2),CCOST(I,1),
     1COSTO(I,1),ACOST(I,1),TCOST(I,1),DMATX(16,I)
  570 FORMAT (1X,1HP,I2,2X,'LIME ADDITION',4X,'DLIME',4X,'CLIME',5X,'PPDPRT32300
     1L',5X,'DTON',13X,'CCOST',4X,'COSTO',4X,'ACOST',4X,'TCOST',6X,'ECF'PRT32400
     2,/,6X,'TO SLUDGE',6X,F9.1,F9.2,F9.1,F9.2,9X,F9.0,3F9.3,F9.2,//)   PRT32500
      GO TO 610                                                         PRT32600
C                                                                       PRT32700
C                                                                       PRT32800
C                   RBC                                                 PRT32900
C                                                                       PRT33000
  580 WRITE (IO,590) I,(DMATX(J,I),J=1,9),(OMATX(J,I),J=1,10)           PRT33100
  590 FORMAT (1X,1HP,I2,2X,'ROTATING',11X,'BOD',4X,'XNSTG',5X,'DEGC',4X,PRT33200
     1'QPABI',4X,'QPANI',6X,'GSS',5X,'BODN',6X,'TSS',5X,'CPDY',/,6X,'BIOPRT33300
     2LOGICAL',5X,2F9.1,3F9.2,2F9.1,2F9.2,/,6X,'CONTACTOR-',/,6X,'FINAL PRT33400
     3SETTLER',5X,'QPAB',5X,'QPAN',4X,'APSTG',5X,'AREA',4X,'FNSTG',4X,'RPRT33500
     4NSTG',4X,'RATIO',5X,'PREM',5X,'QPAT',6X,'AFS',/,21X,2F9.2,2F9.0,2FPRT33600
     59.2,F9.3,F9.2,F9.3,F9.1,/)                                        PRT33700
      WRITE (IO,600) (OMATX(J,I),J=11,17),CCOST(I,1),COSTO(I,1),ACOST(I,PRT33800
     11),TCOST(I,1),DMATX(16,I),CCOST(I,2),COSTO(I,2),ACOST(I,2),TCOST(IPRT33900
     2,2),DMATX(15,I)                                                   PRT34000
  600 FORMAT (24X,'PDSD',5X,'URSS',5X,'NTRN',4X,'NSHFT',4X,'COSTM',4X,'CPRT34100
     1OSTE',4X,'COSTL',/,21X,F9.1,F9.3,2F9.1,3F9.0,//,68X,'CCOST',4X,'COPRT34200
     2STO',4X,'ACOST',4X,'TCOST',6X,'ECF',/,57X,'CONTACTOR',F9.0,3F9.3,FPRT34300
     39.2,//,57X,'FINAL',4X,F9.0,3F9.3,F9.2,/,57X,'SETTLER',//)         PRT34400
  610 CONTINUE                                                          PRT34500
C                                                                       PRT34600
C                                                                       PRT34700
C             OUTPUT FORMAT FOR COSTS OF MISCELLANEOUS FACILITIES       PRT34800
C                                                                       PRT34900
      WRITE (IO,620) CCOST(20,1),COSTO(20,1),ACOST(20,1),TCOST(20,1)    PRT35000
  620 FORMAT (6X,'ADMINISTRATIVE',48X,'CCOST',4X,'COSTO',4X,'ACOST',4X,'PRT35100
     1TCOST',/,6X,'AND LABORATORY',46X,F9.0,3F9.3,//)                   PRT35200
      WRITE (IO,630) CCOST(20,2),COSTO(20,2),ACOST(20,2),TCOST(20,2)    PRT35300
  630 FORMAT (6X,'GARAGE',56X,'CCOST',4X,'COSTO',4X,'ACOST',4X,'TCOST',/PRT35400
     1,6X,'AND SHOP',52X,F9.0,3F9.3,//)                                 PRT35500
      WRITE (IO,640) DMATX(9,20),CCOST(20,3),COSTO(20,3),ACOST(20,3),TCOPRT35600
     1ST(20,3)                                                          PRT35700
  640 FORMAT (6X,'LABORATORY',8X,'XLAB',40X,'CCOST',4X,'COSTO',4X,'ACOSTPRT35800
     1',4X,'TCOST',/,6X,'OPERATION',6X,F9.1,36X,F9.0,3F9.3,//)          PRT35900
      WRITE (IO,650) CCOST(20,4),COSTO(20,4),ACOST(20,4),TCOST(20,4)    PRT36000
  650 FORMAT (6X,'YARDWORK',54X,'CCOST',4X,'COSTO',4X,'ACOST',4X,'TCOST'PRT36100
     1,/,6X,'OPERATION',51X,F9.0,3F9.3,//)                              PRT36200
C                                                                       PRT36300
C                                                                       PRT36400
C             OUTPUT FORMAT FOR TOTAL PLANT COST                        PRT36500
C                                                                       PRT36600
      WRITE (IO,660) (OMATX(J,20),J=17,20)                              PRT36700
  660 FORMAT (1H1,//////,54X,'TOTAL PLANT COST',///,39X,'TOTAL CAPITAL CPRT36800
     1OST = ',F10.0,' DOLLARS',16X,'TOT',//34X,'TOTAL AMORTIZATION COST PRT36900
     2= ',F10.3,' CENTS/1000 GALLONS',5X,'TAMM',//,41X,'TOTAL O + M COSTPRT37000
     3 = ',F10.3,' CENTS/1000 GALLONS',5X,'TOPER',//,37X,'TOTAL TREATMENPRT37100
     4T COST = ',F10.3,' CENTS/1000 GALLONS',5X,'TOTAL',/////)          PRT37200
      WRITE (IO,670) (DMATX(J,20),J=1,10),(OMATX(J,20),J=1,12)          PRT37300
  670 FORMAT (7X,'CCI',9X,'WPI',10X,'RI',9X,'YRS',9X,'DHR',9X,'PCT',10X,PRT37400
     1'UA',7X,'CCINT',8X,'XLAB',8X,'CKWH',//,3F12.3,F12.1,F12.2,F12.3,F1PRT37500
     22.0,2F12.2,F12.3,/////,5X,'RATIO',8X,'TCAP',8X,'YARD',9X,'TCC',7X,PRT37600
     3'XLAND',9X,'ENG',7X,'SUBT1',8X,'FISC',7X,'SUBT2',8X,'XINT',//,F12.PRT37700
     43,9F12.0,///,6X,'ACRE',10X,'AF',//,F12.2,F12.5)                   PRT37800
      RETURN                                                            PRT37900
      END                                                               PRT38000
```

REFERENCES

1. Preliminary Design and Simulation of Conventional Wastewater Renovation Systems Using the Digital Computer," Robert Smith, March 1968, Water Pollution Control Research Series Publication WP-20-9, NTIS-PB215409.

2. "Executive Digital Computer Program for Preliminary Design of Wastewater Treatment Systems," Robert Smith and Richard G. Eilers, August 1968, Water Pollution Control Research Series Publication WP-20-14, NTIS-PB 222765.

3. "Estimating Costs and Manpower Requirements for Conventional Wastewater Treatment Facilities," Black and Veatch Engineers, October 1971, Water Pollution Control Research Series Publication 17090DAN10/71, NTIS-PB 211132.

4. "Computer Evaluation of Sludge Handling and Disposal Costs," Robert Smith and Richard G. Eilers, August 1975, Proceedings of the 1975 National Conference on Municipal Sludge Management and Disposal, pp. 30-59.